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ROYAL AIRCRAFT ESTABLISHMENT

FARNBOROUGH, HANTS

TECHNICAL NOTE No: G.W.239

SOME DATA ON R.T.V.1 FIRINGS RELEVANT TO FUTURE BEAM-RIDING TRIALS

by

G.B.LONGDEN, M.A.

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Technical Note No. GW 239

March, 1953.

ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

Some Data on RTV1 Firings Relevant to Future Beam-Riding Trials

by

G. B. Longden, M.A.

SUMMARY

By mid-June 1952, twenty missiles of the type RTV1e had been fired at Guided Weapons Trials Wing, Aberporth, in the course of the beam-riding Trial C40. This appears to mark an appropriate time to assess some of the features of the trial which are subject to random variations and call for statistical analysis. These include the times of various events in the course of a firing, as well as the slant range, velocity and dispersion of the missile. Means and root mean squared scatters about the means are quoted for some forty variables, and the distributions of the observations shown diagrammatically by means of histograms.

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1 Introduction

1.1 At some convenient stage in the progress of any large and prolonged trial, it is desirable to collect and examine the details concerning one or two aspects which are normally overlooked or taken for granted. Such an analysis may set a standard of practical performance with which to compare the theoretical performance aimed at in the design of the missile or to serve as a basis for assessing the performance of future rounds in the same trial.

Not only is an early analysis useful in the later stages of a trial, but the data collected may provide a basis for the more efficient design of future trials, which share any common ground such as the same type of launcher, or a similar boost or sustainer motor. In particular, trials similar to the one considered here are being planned at LRWE, Australia, and it is hoped that the present note may provide the answers to some of the planners' questions.

1.2 By mid-June, 1952, twenty rounds had been fired of the supersonic beam-riding test vehicle RTV1c. This appears to mark a convenient stage at which to review some of the facts which are best elucidated by statistical analysis.

The present note sets out information collected concerning Trial C40, the trial at GWTW, Aberporth, in which RTV1c missiles are guided along the beam of a modified S.R. 584 radar set. A brief outline of the firings considered is set out in the table forming Appendix I. The purpose of the note is to present a general picture of the course of any one firing and to provide details about a number of features. These include:-

(a) the time for filling the missile with liquid oxygen,

(b) the time at which maximum speed is attained,

(c) the maximum speed,

(d) the time at which the boost separates,

(e) the speed of the missile when the boost separates,

(f) the dispersion of the missile after boost separation,

(g) the dispersion of the guidance beam gathering the missile,

(h) the time when the guidance beam steadies for gathering,

(i) the speed of the missile during the programme,

(j) The slant range of the missile during the programme,

(k) the time when the motor thrust ceases,

(l) the direction of the radar beam-riding axis.

The information concerning beam-riding systems which the trials were designed to supply is not the subject of this note. Such results are presented in detail in reference 1, which covers the first four rounds, and later results provide the basis for comparison in reference 2.

1.3 Almost the entire main text comprises a summary of the results which are derived in a series of appendices. Generally each appendix starts

with a table of observations gathered from the details published by GWTW about each firing. These observations are then summarized in the form of $\bar{x} \pm \sigma_x$ where $\bar{x}$ is the mean and σ_x the root mean squared deviation from the mean (abbreviated to r.m.s. scatter). These two parameters suffice to specify a gaussian probability distribution

$$\frac{dx}{(2\pi)^{\frac{1}{2}}\,\sigma_x} \exp\left\{-\frac{(x-\bar{x})^2}{2\sigma_x^2}\right\}$$

wherever this can be regarded as a reasonable fit to the distribution of the observations.

Salient features of the gaussian probability distribution are as follows. The most probable value of the variable x is the mean value $\bar{x}$ about which the distribution is symmetrical. Deviations (positive or negative) of the variable x from the mean value $\bar{x}$ of an amount greater than σ_x have a probability 32%. Deviations greater than $2\sigma_x$ have a probability 5%. Wherever it is necessary to discard outside chances, it is a common practice to regard the variable as lying between $\bar{x} - 2\sigma_x$ and $\bar{x} + 2\sigma_x$, and to ignore the 5% probability that it lies outside. If the bound on the variable is not symmetrical but one-sided, it may be noted that 84% of the probability accrues to values of x less than $\bar{x} + \sigma_x$ or greater than $\bar{x} - \sigma_x$.

Frequent reference occurs throughout the note to the angular measure known as a mil. In order to conform with the dial markings on US radar sets, of which the ground radar used for guidance is an example, the definition of the mil is that 6400 mils form one complete revolution. Thus 1000 mils equal 0.9817 radian with the result that one mil is only approximately equal to one milli-radian. Conversion from mils to degrees follows from the equality 17.8 mils = 1 degree.

2 Outline of Trial 240

2.1 The RTV1e is a missile of length 17½ feet, body diameter 9½ inches, all-up-weight 615 lbs with four wings of rectangular plan, steered by all-moving tail surfaces in an up-down and left-right type of control. It was designed as a test vehicle for beam-riding guidance and control systems. The round is accelerated to supersonic speed by a tandem boost comprising seven 5 inch rockets. The boost falls away from the round as soon as its impulse is spent and the missile flies on, powered by a liquid fuel motor, which sustains the speed for a further twenty seconds. The missile is gathered in the beam of an SCR 584 radar set, modified for guidance and usually referred to as the 584G. The missile rides in the guidance beam for as long as its speed provides enough lift to control it. More details about the missile and its equipment are available in reference 1 and in the bibliography listed there.

2.2 The course of the trial once the round has been prepared for firing may be outlined roughly as follows.

(a) Approximately 500 seconds before firing. Filling of the liquid oxygen tank in the missile commences.

(b) 120 seconds before firing. As soon as liquid oxygen starts blowing off, indicating that the missile tank is full, the fire-controller starts an automatic sequence which fixes the time of fire to occur

two minutes later. In the course of this sequence, the guidance and control circuits are warmed up on external supplies and then switched over to the internal batteries.

(c) 15 seconds before firing. The umbilical plug is ejected, cutting off all monitoring of the missile except by the telemetry.

(d) Firing. The missile accelerates up the launcher aligned at an elevation to the horizontal (quadrant elevation or QE) of 30 degrees on a bearing of 355 degrees.

(e) 3 seconds after firing. The boost motor separates from the missile. Maximum speed is attained roughly $\frac{1}{4}$ second earlier than this. The act of separation initiates an automatic sequence in the missile which ignites the sustainer motor after $\frac{1}{2}$ second, switches on the roll stabilization 1 second after separation and switches through the guidance commands 2 seconds after separation.

(f) 6½ seconds after firing. An optical tracker to which the 584G has been ganged and harmonized is aligned to within $\pm$ 10 mils of the sight line to the missile and is then left steady, so that the missile can recover to the beam axis.

(g) 10 seconds after firing. The missile has settled in the steady guidance beam and can be considered gathered. The programme set for the trial is started by an automatic unit which moves the guidance beam.

(h) 26 seconds after firing. The sustainer motor ceases to thrust and the missile starts to decelerate rapidly at about 40 ft/sec^2. With the fall in speed and the increased altitude, the aerodynamic lift decreases and the missile is slacker to control. The programme for the trial is completed by this time.

After this brief outline, the stages in the course of the firing will be analysed in greater detail.

3 Filling with Liquid Oxygen

3.1 Once the filling of liquid oxygen has begun, the round must be fired or else left for many hours until all the oxygen has evaporated and the round warmed up again to ambient temperature. At any time before the instant of fire, the sequence of operations may be stopped and firing prevented, but if a fault occurs while there is oxygen in the missile tank, firing of that round will be delayed for a day.

3.2 If all goes well, the instant of firing occurs between seven and eleven minutes after the start of filling the liquid oxygen tank. The firing is unlikely to take place earlier than seven minutes from the commencement of filling because of the time taken by the operation. For the first few minutes the missile tank scarcely fills at all, since the walls are not sufficiently cool and boil away the liquid oxygen as fast as it pours in. During this period, the walls of the tank cool until they are below the boiling point of liquid oxygen, and then the tank starts to fill. The instant of firing must not be delayed beyond three and a half minutes after the tank becomes full, for if the cordite expulsion charge is chilled too much, it fails to produce enough pressure to initiate the burning of the sustainer motor.

3.3 Because there is no gauge to measure the contents of the missile tank, it is difficult to control the instant at which the tank becomes

full and starts to vent. Hitherto, there has been no need to achieve a constant filling time, and the figures analysed in Appendix II show that the operation takes a variable time of

6 minutes 33 seconds $\pm$ 55 seconds

of which the first time represents the mean and the second the r.m.s. scatter. These results were from 25 rounds of the type RTV1 taken over a period of four months. Greater consistency appears among the last twenty of these for which the times were

6 minutes 26 seconds $\pm$ 37 seconds.

Over the last ten of these observations there was some attempt to achieve a constant filling period, and the resulting times were

6 minutes 34 seconds $\pm$ 24 seconds.

By controlling the rate of filling, it may be possible to alter the time at which the missile tank is completely full, but with no gauge on the tank, it appears optimistic to hope that the scatter can be reduced below 15 seconds. If it can be, and if it is assumed that a gaussian distribution applies, 95% of the filling periods would lie between six and seven minutes.

3.4 As soon as the liquid oxygen tank is full, it vents a spurt of "steam". This is reported to the fire-controller who initiates the automatic two-minute sequence to firing. During the two minutes before the sustainer motor is called upon to ignite, about 10% of the liquid oxygen boils away and leaves sufficient ullage space for the cordite expulsion charge in the next compartment to function properly. It is necessary that the oxygen tank should be full at the start of the two-minute sequence in order that the motor shall not fail early through lack of oxygen.

It appears possible that if a fixed timing sequence were required, the initiation of the two-minute sequence could be delayed by up to a minute if necessary, so that it would almost always occur exactly seven minutes after the commencement of filling. During the delay, the oxygen bottle would stand by and continue to pour oxygen into the missile tank in order to keep it full. Unless this delay in starting the two-minute sequence can be prolonged beyond a minute, there is no disposable time in initiating the sequence which leads to firing.

The variation in filling time is a measure of uncertainty and is not a tolerance at the disposal of the fire-controller.

3.5 During the two minute sequence, the guidance and control equipment is run up on external supplies, and monitored as a last-minute check. At one minute to firing, the 584G transmitter is switched on and at 30 secs to firing, the missile is switched to its internal supplies. A quarter of a minute is available for monitoring these. At 15 secs to firing, the plug connection is ejected from the missile and all monitoring ceases, except at those points which transmit over the telemetry channels. At this stage, some short delay could be introduced before firing if it should prove necessary. Heating of the receiver imposes an upper bound of perhaps ten seconds to any such pause, as it causes drifts of the electrical levels which might prove serious if they went too far. It is not advisable to introduce a pause in the firing sequence any later than ten seconds to firing, since the oil unit is initiated at eight seconds to firing. The oil unit provides hydraulic power to the actuators and as it acts on a non-return system, oil is steadily expended. If the oil unit starts working too early, the actuators would fail early in flight.

4 Dispersion of the Missiles

4.1 The act of firing consists of igniting the boost motor, and is accomplished through the automatic time switch which starts two minutes before firing. The round accelerates up the launcher and moves off with an acceleration of about 15g.

The results detailed in Appendix III show that the round (comprising missile and boost) attains a maximum speed of 1581 ft/sec with an r.m.s. scatter of 22 ft/sec at a time after firing of 3.40 secs with an r.m.s. scatter of 0.25 sec. At approximately a quarter of a second later, the drag on the boost exceeds its diminishing thrust, and the missile flies ahead since it experiences less drag. This separation occurs at a missile speed of

$$1566 \pm 24 \text{ ft/sec}$$

at a time after firing of

$$3.67 \pm 0.25 \text{ seconds.}$$

The separation occurs at a slant range from the guidance set of about

$$4100 \pm 300 \text{ feet.}$$

4.2 The act of separation initiates in the missile a short sequence of events. Half a second after separation, the sustainer motor is ignited. Separation of the boost and ignition of the liquid fuel motor cause mechanical shocks and vibration which may produce spurious electrical signals in both the roll-stabilisation and the guidance equipment. For this reason, the roll stabilisation is switched on half a second after the motor has lit. After this, one second is allowed for the missile to attain its correct roll attitude before the guidance signals are switched on.

4.3 Up to about six seconds from firing, the missile flies unguided. During this period it passes through the two operations of launching and separating from the boost, both of which cause unpredictable impulses. As a result of these, and also malalignment of the boost and missile, individual rounds are dispersed about the mean path which they might be expected to follow under the influence of gravity and an ideal thrust. Appendix IV contains a discussion of the observations, which are plotted in various ways in Figs. 6-21. All these observations are referred to a fixed straight line which has been called the gathering line, the mean of the directions in which the radar beam is left steady during the operation of gathering the missile into the beam (see the next chapter, section 5.2). This gathering line is on the same bearing as the line of fire of the launcher (bearing 355 degrees) and at an elevation of 19 degrees above the horizon, 11 degrees below that of the launcher.

4.4 The displacements of the rounds from the gathering line at 4, 5 and 6 seconds after firing are shown in Figs. 6, 7 and 8. These are followed by Figs. 9-18 which resolve the displacements into up/down and left/right components and portray the distributions of these components. Four of the drawings concern the differences between the successive readings and so represent the mean lateral velocities of the rounds. The final three figures numbered 19-21 show the dispersions of the rounds as they would appear in a telescope centred on the gathering line. Of the fifteen rounds which were still flying at 6 seconds after firing, all appear to stay within a field of view of ± 4 degrees between 4 and 6 seconds from firing. The circle on the figures shows the field of view

of the present optical tracker (55 mils = 3 degrees in radius) and it can be seen that twelve of the rounds remain within it over the same period 4-6 seconds. It seems that at some instant, all 15 rounds would have been in the view of the present optical tracker if it had been pointed along the gathering line.

4.5 The table below shows a brief summary of the displacements of the missiles from the gathering line at four, five and six seconds after firing.

Displacements of Missile from Gathering Line

Gathering line is at elevation 19°, bearing 355°.

Time after firing (seconds)	4		5		6	
Displacement	L/R	U/D	L/R	U/D	L/R	U/D
Mean displacement (feet)	-47	4	-66	26	-57	31
R.m.s. scatter (feet)	134	105	192	140	244	184

The distributions of these observations appear to vary as the time increases. Just after separation of the boost at four seconds after firing, Figs. 9 and 12 show that a normal gaussian distribution would be a reasonable fit to both the distributions of the left/right and up/down components of the displacements. At five seconds after firing, Figs. 10 and 13 show evidence of three humps in the distributions, and by six seconds after firing, there is a distinct indication of a triple-peaked distribution of the components of the displacements.

5 Gathering the Missiles

5.1 Once the guidance equipment in the missile has been switched in (between $5\frac{1}{2}$ and 6 seconds after firing), it is possible to gather the missile into the guidance radar beam. Since the direction of the radar beam is immaterial for the conduct of the trial (apart from the safety limits of the range), it is possible to point the beam roughly at the missile and allow the beam riding guidance to steer the missile into the centre of the beam. This completes the gathering phase. It dispenses with the need for separate gathering equipment, which would be essential in any beam-riding weapon system where the guidance radar would normally be engaged in tracking a target.

5.2 The means adopted for gathering the missile is to gang the dish of the SCR 584G to an M2 type optical tracker which is controlled by two operators, one for elevation and one for bearing. (See reference 4.) As soon as the sight line from the optical tracker to the missile becomes reasonably stationary, these operators centre the cross-wires of their telescopes on the missile. When the missile appears within a box ± 10 mils from the centre, the optical tracker is left steady (referred to as 'locking' the beam) and the missile allowed to recover into the stationary beam. The mean of the directions of the guidance beam when it is left steady for gathering the missile has been called the gathering line. It is at an elevation of 19 degrees above horizontal, on a bearing of 355 degrees. It points at an elevation 11 degrees below that of the launcher and on the same bearing.

5.3 In order to ensure complete success in gathering, it has been the practice for the operators of the optical tracker to follow the missile off the launcher. This task is simplified as much as possible by

choosing the line of fire 355 degrees so that the launcher bears straight away from the optical tracker and the radar. However much this reduces the turning needed in azimuth, high rates of turn (50 mils/sec) are still needed in elevation. Now that there are available the results on dispersion detailed above, it appears to be possible to leave the optical tracker centred on the gathering line, and to wait until the missile appears in the field of view before moving it. By reducing the elevation turned through from 350 mils to about 50 mils, this might help to speed the operation of gathering.

It cannot be expected to reduce the dispersion of the beam about the gathering line. The twelve observations of beam dispersion considered in Appendix V are plotted in Fig.27. This may be compared with Fig.21, which shows the dispersion of the missiles at 6 seconds after firing, i.e. at about the time when guidance is switched in. The scatter of the beam directions after the missiles have been gathered appears no larger than the scatter of the sight lines to the missiles just before gathering. This implies that the present technique of gathering is reasonably efficient and contributes very little to the dispersion of the beam about the gathering line.

5.4 The observations from which Fig.27 was drawn are listed in Appendix V together with the details of the distributions suggested for the elevation and bearing of the guidance beam when it is held steady during gathering. These distributions are not simple gaussian ones but need to be triple-humped to correspond with those of the dispersion of the missile before gathering. The actual distributions of the observed bearings and elevations are shown in Figs. 25 and 26. The outcome of the discussion in the appendix is that about 95% of the rounds are gathered on bearings between ± 55 mils (± 3 degrees) of the line of fire, and 95% of the rounds are gathered at elevations between ± 44 mils (± 2.5 degrees) of the gathering line, which is at an elevation of 338 mils (19 degrees) above horizontal.

5.5 The slant range of the missile when the guidance beam becomes steady is

$$6300 \pm 1600 \text{ feet.}$$

The time after firing at which the guidance beam becomes steady is

$$6.80 \pm 1.03 \text{ seconds.}$$

The mean of these times is only one second after the missile guidance has been switched in. Since the guidance beam does not move very rapidly just before it comes to rest, it appears that many of the rounds commence recovery into a nearly stationary beam as soon as guidance begins.

If the distribution of the times to when the beam steadies is assumed to be gaussian, the beam would have 95% probability of being stationary by 8.5 seconds after the instant of firing. Since the missile may appear as much as 10 mils from the centre of the beam when it steadies, about 2 seconds must be allowed for the recovery from this displacement. Thus it is considered that by 10 seconds after firing, most of the missiles have been gathered into the guidance beam, and it is possible to start up the programme set for the trial.

6 The Programme Period

6.1 For the next 15 secs after gathering has been completed, the missile is directed by movements of the guidance beam according to the desired programme. It is shown in Appendix VI that, during this period, the speed of the missile decreases on an average about 10% while the slant range

from the guidance set more than doubles. Figs. 31-35 show the distributions of velocities at 10, 15, 20, 25 and 30 seconds after firing and Figs. 36-40 show the corresponding distributions of slant ranges.

The mean speed between 10 and 25 seconds after firing approximates closely to a constant deceleration at 10 ft/sec^2 from 1380 ft/sec to 1230 ft/sec. An approximation based on the same deceleration appears to fit the slant ranges also. Figs. 41 and 42 show the fitted approximations to the velocity and the slant range of the missile and indicate the magnitude of the r.m.s. scatter. The scatter of the actual observed speeds about the fitted mean curve is considerable and increases almost proportionally with the time after firing from 64 ft/sec to 160 ft/sec. This has been indicated by the broken lines in Fig.41. The r.m.s. scatter of the observed slant ranges about the fitted curve appears to increase almost as the square of the time from firing, increasing from 400 feet to 1700 feet.

These facts suggest that all the missiles achieve roughly the same speed soon after launch but that the individual rounds decelerate at a rate which varies from missile to missile according to the distribution

$$10.0 \pm 6.4 \text{ ft/sec}^2.$$

6.2 The motor was designed to maintain a constant speed of 1300 ft/sec. At the heights reached by the missile during the programme period 1300 ft/sec represents a Mach number of $\bar{M} = 1.2$. Much below this speed, the aerodynamic stiffness of the missile response falls away and the control becomes undesirably slack. By 25 seconds after firing, the average speed of the missiles has fallen to 1230 ft/sec ($M = 1.14$). It is shown in Appendix VI that at about this time the motor ceases to thrust, after which the deceleration is rapid at 40 ft/sec^2. At 28.7 $\pm$ 2.7 seconds after firing, the missile speed falls through the value 1100 ft/sec. By 30 seconds after firing, the average speed of the missiles is sub-sonic. For this reason, it is generally arranged that the useful part of the beam programme is completed by 25 seconds after firing.

7 Conclusion

7.1 The note has shown how a missile type RTV1e is fired in the course of Trial C40 at GWTW, Aberporth. The speed, slant range and dispersion together with the times of major events in the course of the firing have been summarized for the first twenty rounds fired up to mid-June, 1952.

7.2 During the operations of launching and boost separation, the missiles suffer random dispersions resulting, at six seconds after firing, in displacements from the mean of the order of 200 feet and lateral speeds of the order of 50 feet/second. If the present optical tracker had been pointed at an elevation eleven degrees below that of the launcher elevation of thirty degrees, and on the same bearing, all the missiles would have appeared at some time inside its $\pm$ 3 degrees field of view. With a field of view of $\pm$ 4 degrees, all the missiles which were still flying correctly would have been visible over the whole time interval from four to six seconds after firing.

7.3 During the programme period from ten to twenty-five seconds after firing the missile, the average speed of the missiles decreases at 10 ft/sec^2 from 1380 ft/sec to 1230 ft/sec. The scatter in speeds between individual missiles increases from a root mean squared deviation of sixty feet/second to one hundred and fifty feet/second.

During the same period, the mean slant range of the missiles increases from 13,500 feet to 33,000 feet. The scatter in slant ranges between individual missiles increases from a root mean squared deviation of 370 feet to 1740 feet.

7.4 From sixty determinations, the beam-riding direction of the guidance radar aerial measured by means of a wing-aerial mounted on a mast appears to be invariant relative to the radar dish. Relative to the reference telescope fixed to the radar dish, the beam-riding direction is at an elevation of 11.6 mils down and a bearing of 1.1 mils left. The accuracy of each determination of the beam-riding direction has a root mean squared scatter of 0.7 mils in both elevation and bearing. The accuracy of harmonizing a movable reference telescope with the beam-riding direction has a root mean squared scatter of 0.8 mils in both elevation and bearing.

Acknowledgement

The author wishes to emphasize that throughout the preparation of this note he has acted merely as a collector of information. He would like to thank all those who have answered his many questions on topics connected with this trial. In particular, he is grateful to Messrs. R. J. Buller, J. E. A. Harrison, K. Jackson and A. S. Younger of GWTW. Aberporth: and to Mr. D. C. Stenning, Major A. L. Riddle, Lt/Cdr D. Moore and Mr. D. E. Postle of RAE/GWD.

REFERENCES

No.	Author	Title, etc.
1	W.R. Thomas D.C. Stenning	The Beam-Riding Trials of the Supersonic Test Vehicle RTV1. Part I. Rounds 1-4. RAE Tech Note No. GW 151. Nov. 1951.
2	J.J. Gait	A Comparison of Theory and Flight Results for the Non-Linear Weave Motion of the RTV1 Beam Rider. RAE Report No. GW 13. July 1952.
3	J.E.A. Harrison	Apparent Shift of beam riding axis on C40, Round 4. Letter to Major A. L. Riddle. Oct. 1951. GWTW:- ABT 14/15.
4	J.E.A. Harrison	Measurement of some possible sources of Disturbance to the beam of a Guidance Radar (SCR 584). Part I. Remotely controlled aerial. RAE Tech Note No. GW 105. Feb. 1951.
5	J.E.A. Harrison A.S. Younger	Beam laying procedure and instrumentation accuracy on Guidance Trials. GW/S/154/2/RWP/9. March 1952.

Attached:- Appendices I to VII
Drgs. GW/P/4243 to 4266
Detachable Abstract Cards

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APPENDIX I

Summary of the First Twenty Firings in Trial C40

Round Number	Projectile Number	Date Fired	Remarks
1	161	11.5.51	Exploded about time of boost separation.
2	216	31.5.51	Roll gyro precessed and provided wrong datum. Rode beam but in a divergent spiral.
3	215	12.7.51	Broke up about 12 seconds after firing. Gathering and recovery into the beam successful.
4	219	31.8.51	First successful beam rider: beam stationary.
5	218	24.10.51	Oil unit failure: self destroyed 14 seconds after firing.
6	234	12.11.51	Exploded about time of boost separation.
7	217	10.12.51	Failed to roll-stabilize: self destroyed 10 seconds after firing.
8	284	12.12.51	Successful night shoot. Rode a beam stepped through 6 mils to the right at 25 seconds.
9	235	28.1.52	Intermittent fault between guidance and control equipment.
10	287	29.1.52	Propulsion failed.
11	236	26.2.52	Rode beam stepped to the right. Thrust of motor ceased early.
12	286	27.2.52	Propulsion failed.
13	285	5.3.52	Failed to remain in beam moving upwards at 20 mils/sec.
14	288	11.3.52	Successfully rode beam moving left at 10 mils/sec.
15	304	12.3.52	Exploded after violent boost separation.
16	349	26.3.52	Rode beam stepped diagonally left and up. Thrust of motor low.
17	355	7.5.52	Faulty beam programme.
18	330	23.5.52	Rode beam stepped diagonally. New configuration with accelerometers forward. Fins locked 20 seconds after firing.
19	348	29.5.52	Failed to remain in beam accelerating left at 5 mils/sec^2 up to 30 mils/sec. Motor failure at 14 seconds.
20	350	17.6.52	Boost failed.

APPENDIX II

Time for Filling Missile with Liquid Oxygen

Observation	1	2	3	4	5	6	7	8	
Trial	C41	C41	C41	C40	C40	C40	C37	C40	
Round number	4	5	6	11	12	13	20	14	
Projectile number	275	276	280	236	286	285	326	288	
Date. 1952.	11-2	11-2	11-2	26-2	27-2	5-3	5-3	11-3	
Time (mins & secs)	5m 37	9m 52	5m 49	6m 32	7m 03	5m 43	5m 06	5m 34	
Observation	9	10	11	12	13	14	15	16	
Trial	XP8	C40	A3/1	C40	C37	C37	C40	A9	
Round number	2	15	17	16	21	22	17	38	
Projectile number	302	304	337	349	354	351	355	335	
Date. 1952.	12-3	12-3	21-3	26-3	28-4	29-4	7-5	12-5	
Time (mins & secs)	6m 08	6m 08	7m 13	5m 54	7m 01	7m 30	7m 00	6m 27	
Observation	17	18	19	20	21	22	23	24	25
Trial	A3/1	A3/1	A3/1	A9	C40	A9	C40	C40	A9
Round number	20	21	22	39	18	40	19	20	41
Projectile number	246	247	338	336	330	382	348	350	381
Date. 1952.	12-5	16-5	16-5	20-5	23-5	26-5	29-5	17-6	19-6
Time (mins & secs)	6m 33	7m 02	7m 30	6m 14	6m 30	6m 12	6m 33	6m 29	6m 00

The filling times quoted above were supplied by Mr. R. J. Duller of GWTW, Aberporth. They are plotted in a histogram in Fig.1.

Take an origin in time at 6 minutes 30 seconds. Successive deviations from this are (in seconds):-

-53 +202 -41 +2 +33 -47 -84 -56 -22 -22 +43 -36 +31

+60 +30 -3 +3 +32 +60 -16 +0 -18 +3 -1 -30.

Thus the mean observation is $\frac{1}{25} \times 70 = 2.8.$

Squared deviations may be written down from an inspection of a table of squares and summed rapidly.

The mean squared deviation from 6 mins 30 secs is 2979.76 $\sec^2$. Thus the mean squared deviation from the mean is

$$2979.76 - (2.8)^2 = 2971.92.$$

Therefore, the root mean squared deviation from the mean is

54.52 seconds.

The observations may be described by a mean and an r.m.s. scatter of

6 mins 33 secs $\pm$ 55 seconds.

By a similar analysis, the last twenty observations give a mean and r.m.s. scatter of

6 mins 26 secs $\pm$ 37 seconds.

The last ten observations give a mean and an r.m.s. scatter of

6 mins 34 secs $\pm$ 24 seconds.

The histogram of these observations shown in Fig.1 indicates that the results would be reasonably represented by a gaussian curve apart from the second observation. There appears to be some tendency to skewness with higher probability of positive deviations from the mean than for negative deviations. This is understandable since the operation of filling is certain to take up at least some particular length of time whereas it might last out over any long interval.

APPENDIX III

Times and Velocities at Maximum Speed and Boost Separation

Round number CL0/		1	2	3	4	5	6	7
Maximum speed	ft/sec	1615	1590	1590	1590	1550	1550	1560
Time	secs	3.25	3.30	3.55	3.30	3.65	3.65	3.45
Speed at separation	ft/sec	-	1576	1575	1575	1540	1540	1547
Time	secs	-	3.55	3.69	3.64	4.07	4.09	3.64
Slant range	thousands of feet	-	3.7	3.7	4.2	4.8	-	4.0
Round number CL0/		**8**	**9**	**10**	**11**	**12**	**13**	**14**
Maximum speed	ft/sec	1580	1532	1575	1591	1619	1613	1579
Time	secs	3.50	3.35	3.20	3.18	2.96	2.93	3.51
Speed at separation	ft/sec	1550	1517	1556	1574	1609	1608	1571
Time	secs	3.70	3.58	3.51	3.64	3.20	3.28	3.80
Slant range	thousands of feet	4.0	3.7	4.0	4.0	3.9	3.6	4.3
Round number CL0/		**15**	**16**	**17**	**18**	**19**	**20**	
Maximum speed	ft/sec	1585	1560	1579	1580	1600	-	
Time	secs	3.59	3.80	3.67	3.30	3.20	-	
Speed at separation	ft/sec	1580	1546	1565	1572	1597	-	
Time	secs	3.67	4.07	4.00	3.61	3.39	-	
Slant range	thousands of feet	-	4.6	4.6	4.2	4.1	-	

These results have been collected wherever possible from the minutes of the firing conferences held periodically at RAE, Farnborough to consider the results of each firing.

Successive observations of the missile speed are quoted at intervals of about one twentieth of a second. The times quoted in the above table are liable to errors in measurement considerably greater than this. The time of maximum velocity if measured from a graph requires estimation of where the peak of a curve lies. If it is read from a table, small errors in the measurement of the speed are likely to disguise where the true maximum occurs. The time of boost separation is liable to varying interpretation between different observers scanning the films or telemetry records, and this has produced a discrepancy between two different estimates for Round 14 of 0.09 sec.

The 19 observations of maximum speed give a mean and an r.m.s. scatter of

$$1581 \pm 22 \text{ ft/sec.}$$

The 19 observations of the time after firing of maximum speed give a mean and an r.m.s. scatter of

$$3.40 \pm 0.25 \text{ seconds.}$$

The 18 observations of the missile speed at boost separation give a mean and an r.m.s. scatter of

$$1566 \pm 24 \text{ ft/sec.}$$

The 18 observations of the time to boost separation give a mean and an r.m.s. scatter of

$$3.67 \pm 0.25 \text{ seconds.}$$

The distributions of these results are shown in Figs. 2-5.

The observations of the slant range of the missile when it separates from the boost have been read from the published sheets of the radar range. No such records were published for rounds 6 and 15, both of which exploded soon after separation had taken place. The observations for rounds 11 and 13 were read from the kine-theodolite determination of range since no radar ranges were quoted in the vicinity of separation.

The 16 observations of the slant range of the missile from the guidance radar at boost separation give a mean and an r.m.s. scatter of

$$4.1 \pm 0.3 \text{ thousands of feet.}$$

APPENDIX IV

Dispersion of the Missile at Launch and at Boost Separation

Displacement of the Missile from the Gathering Line
at 4, 5, 6 seconds after Firing.

	Displacement feet						Average speed ft/sec			
Time after Firing	4 secs		5 secs		6 secs		4-5 secs		5-6 secs	
Round Number	L/R	U/D	L/R	U/D	L/R	U/D	L/R	U/D	L/R	U/D
2	203	112	305	176	413	185	102	64	108	9
3	-151	182	-241	166	-311	132	-90	-16	-70	-34
4	-139	46	-4	133	161	197	135	87	165	64
5	10	-29	-23	-37	-46	-99	-33	-8	-23	-62
7	70	-43	60	-45	20	-34	-10	-2	-40	11
8	-23	171	17	254	20	335	40	83	3	81
9	-212	-65	-332	-57	X	X	-120	8	X	X
10	-175	-39	-250	-53	-336	-78	-75	-14	-86	-25
11	-137	-8	-212	-9	-316	-16	-75	-1	-104	-7
12	-30	141	-53	223	-59	270	-23	82	-6	47
13	-247	83	-376	178	-453	247	-129	95	-77	69
14	150	-39	202	-2	257	-4	52	37	55	-2
16	66	-71	87	-75	95	-90	21	-4	8	-15
17	24	-97	5	-82	-13	-66	-19	15	-18	16
18	50	-203	65	-269	95	-366	15	-66	30	-97
19	-217	-75	-308	-86	-377	-143	-91	-11	-69	-57

These distances and speeds have been calculated from the records of missile position obtained by kine-theodolites. They are measured normal to a fixed direction which will be called the gathering line, since it is the mean line on which the missiles are gathered into the radar beam. This gathering line points from the guidance radar set at an elevation of 19 degrees (338 mils) above the horizon on a bearing 355 degrees (-89 mils from true north). As read on the dials of the SCR 584G, this direction would be at an elevation of 340 mils and a bearing of -105 mils from the radar north. The launcher from which the round flies points on the same bearing as the gathering line but is inclined at an elevation of 30 degrees above horizontal.

The kine-theodolite determination of the missile position is quoted in the published trajectory data sheets in the form of three coordinates based on the guidance radar as origin: the height H, the northing N and the easting E. Those coordinates are referred to the line of fire so that the northing is measured along a horizontal line on a bearing 355 degrees, the height vertically and the easting normal to both the other directions. These distances should be accurate to within 5 feet. They may be converted into displacements normal to the gathering line, X the left/right displacement and Y the up/down displacement, by means of the following relations:-

$$X = E$$

$$Y = H \cos 19^{\circ} - N \sin 19^{\circ}.$$

These displacements X and Y can be calculated for the instants shown in the published data sheets, which are spaced at intervals of time a quarter second apart. The displacements at 4, 5 and 6 seconds after firing are found by interpolating.

The displacements of the rounds at 4, 5 and 6 seconds after firing are plotted in Figs. 6, 7, 8. Since separation of the boost occurs about 3.7 seconds after firing, the displacements at 4 seconds after firing are almost entirely due to the dispersion of the round off the launcher. Figs. 9 and 12 portray the distributions of the left/right and up/down displacements separately and show that both sets of displacements are grouped closely together. By 6 seconds after firing, the effect of any extra dispersion at boost separation has become apparent. At this time the guidance signals have only just been switched on and so have not had much time to take effect. The separate distributions of the left/right and up/down displacements are shown in Figs. 10 and 13 for 5 seconds after firing and in Figs. 11 and 14 for 6 seconds after firing.

The average lateral speeds over the time intervals 4-5 seconds and 5-6 seconds may be deduced by subtracting the values of displacement quoted above. These velocities form the last four columns in the table. The distributions in the lateral velocities in the left/right and up/down directions are shown by Figs. 15-18.

The following table shows the mean and r.m.s. scatter which is produced by combining all the observations in each of the ten columns of the table above. This too shows how the dispersions of the missiles open out as the time increases.

Time after firing (secs)	Observation	Number of observations	Mean (feet)	R.m.s. scatter (feet)
4	Left/Right displacement	16	-47	134
5	"	16	-66	192
6	"	15	-57	244
4-5	Left/Right speed	16	-19	73
5-6	"	15	-8	72
4	Up/Down displacement	16	4	105
5	"	16	26	140
6	"	15	31	184
4-5	Up/Down speed	16	23	47
5-6	"	15	-1	50

Inspection of Figs. 11 and 14 which show the distributions of the displacements at 6 seconds after firing indicates that the missiles tend to sort themselves into three groups. There is little sign of three groups present in Figs. 9 and 12 which show the displacements two seconds earlier, and so it may be deduced that the act of boost separation either imparts to the missile a large impulse or a small one. With reference to Fig.14, the missile either suffers a small shock and flies on with small deviation like eight of the rounds, or else it diverges upwards like rounds 2, 3, 4, 8, 12, 13 or downwards like round 18.

The subdivision into rounds which fly high, low and in between is disputable. On a basis of the up/down velocity, it appears possible to set a boundary at 50 ft/sec and call those rounds high flyers which have a greater velocity than this. It would suggest that four rounds numbered 4, 8, 12 and 13 flew high, with round 2 doubtful since the two values

observed straddle the boundary. However, on a basis of up/down displacement, it appears possible to set a similar boundary at 100 feet from the chosen origin, and this suggests that the six rounds 2, 3, 4, 8, 12, 13 flew high. The inclusion of round 3 amongst the high flyers is not surprising since it appears to have undergone an unusually small tip-off from the launcher, and so was already flying high by the time of boost separation. At separation it suffered only slight further dispersion and so does not appear amongst those with a large upward velocity. It may be noted that the launcher was shortened after a few rounds had been fired in this trial, which may account for the early rounds flying higher than the later ones.

In a similar way it is possible to set a lower boundary at -50 ft/sec in terms of up/down speed and -100 feet in terms of up/down displacement. This leads to the conclusion that round 18 flew low. All the remaining nine rounds were comparatively undeviated at either launch or separation and between 4 and 6 seconds after firing flew within 100 feet of the gathering line with a lateral speed less than 50 ft/sec in the up/down direction.

Similar considerations apply to the left/right coordinate, which is the horizontal displacement from the vertical plane containing the line of fire and the gathering line. With these horizontal deviations, the distinction between left, middle and right flyers is more difficult.

Based on a grouping into velocities, the following table summarizes the information as a mean and r.m.s. scatter over the period 4 to 6 seconds after firing.

<u>Average Lateral Speed from 4 to 6 seconds</u>

Direction		Round Numbers	Number of Observations	Mean ft/sec	R.m.s. scatter ft/sec
Horizontal) Left/Right)		All	16	-10	71
	Left	3,9,10,11,13,19	6	-92	12
	Middle	5,7,8,12,16,17,18	7	-4	21
	Right	2,4,14	3	102	39
Vertical) Up/Down)		All	16	11	47
	Up	4,8,12,13	4	77	6
	Middle	2,3,5,7,9,10,11,14,16,17,19	11	-4	22
	Down	18	1	-82	0

Based on the same grouping as in the table above, the following table shows the left/right and up/down displacements from the gathering line at four, five and six seconds after firing.

/Group

<u>Group Displacements from the Gathering Line at 4, 5, 6 seconds after Firing</u>

Time after firing (secs)		4			5			6		
Direction		Number of Observations	Mean feet	R.m.s. scatter feet	Number of Observations	Mean feet	R.m.s. scatter feet	Number of Observations	Mean feet	R.m.s. scatter feet
Left/Right	All	16	-47	134	16	-66	192	15	-57	244
	Left	6	-190	39	6	-285	56	5	-359	53
	Middle	7	24	38	7	23	47	7	16	57
	Right	3	71	150	3	168	129	3	277	104
Up/Down	All	16	4	105	16	26	140	15	31	184
	Up	4	110	49	4	197	46	4	262	50
	Middle	11	-16	82	11	-9	89	10	-20	99
	Down	1	-203	-	1	-269	-	1	-366	-

A comparison of the distribution of the vertical displacements in Fig.14 with the distributions of vertical velocities in Figs. 17 and 18 shows that there is considerable correlation between the displacement of the missile and its speed normal to the gathering line. Considerable correlation may be expected between the position 6 seconds after firing and the mean velocities for the previous two seconds since the position of the round is the cumulation of the effect of its lateral velocity. The correlation coefficient between the up/down displacement of the round 6 seconds after firing (Fig.14) and the average up/down velocity between 4 and 6 seconds is

$$0.903.$$

Similarly, the horizontal displacement of the missile (Fig.11) is correlated with the horizontal lateral velocity with a coefficient

$$0.906.$$

As a further step, it appears natural to investigate the correlation between the position of the round about the time of boost separation (at 4 seconds after firing) and the mean lateral velocity subsequent to this. The correlation between the up/down displacement of the rounds 4 seconds after firing (Fig.12) and the mean up/down velocity between 4 and 6 seconds after firing has a coefficient

$$0.697.$$

The corresponding coefficient between the left/right displacement (Fig.9) and the mean left/right velocity just afterwards is

$$0.747.$$

These coefficients mean that if, for example, the up/down displacement Y of the missile 4 seconds after firing is known, the uncertainty of the up/down velocity $\dot{Y}$ can be reduced from an r.m.s. scatter of 47 ft/sec to 34 ft/sec; by using the regression line

$$\dot{Y} = 0.316\, Y + 9.$$

This line represents the best straight line fit between the velocity and displacement in the sense of least total squared dispersion about it. In other words the scatter in the up/down lateral velocity after boost separation may be resolved into two components. The total root mean squared scatter of 47 ft/sec may be accounted for by a scatter of 33 ft/sec which depends linearly on the position of the round together with a scatter of 34 ft/sec which is independent of the position. It may be assumed that the cause of the scatter which is independent of position is a random impulse arising during boost separation.

Similarly correlation with the left/right dispersion X at 4 seconds after firing can reduce the uncertainty of the left/right velocity $\dot{X}$ in the next two seconds from an r.m.s. scatter of 71 ft/sec to 47 ft/sec, by using the regression line

$$\dot{X} = 0.395\, X + 5.$$

Thus the total root mean squared scatter of 71 ft/sec in the left/right velocity between 4 and 6 seconds after firing may be resolved into a scatter of 53 ft/sec which depends linearly on the position of the round at 4 seconds after firing together with a scatter of 47 ft/sec arising from boost separation.

The components of the velocity scatter may be resolved still further by considering the causes of the lateral displacements of the rounds at 4 seconds after firing. If the horizontal displacement X at four seconds

after firing were due entirely to an impulse dealt to the round as it left the launcher, the horizontal lateral velocity at 4 seconds after firing would be $\frac{1}{4}$ X ft/sec. On the other hand, if the horizontal dispersion builds up from an acceleration due to misalignment of the boost, the horizontal lateral velocity at 4 seconds after firing would be $\frac{1}{2}$ X ft/sec. Since the observed velocity lies between 0.25 X and 0.5 X, it appears that the mean lateral velocity after boost separation can be accounted for by a combination of these two causes. Since, corresponding to a particular displacement of the round at 4 seconds after firing, the velocity caused by misalignment of the boost is twice as large as that caused by launching dispersion, it is possible to assess the relative sizes of the contributions from each cause.

Suppose that the scatter in the lateral velocities of the rounds after separation arises from three independent causes:

(a) launching dispersion - a random impulsive velocity arising when the round leaves the launcher caused by cross-wind or tip-off;

(b) boost misalignment - a steady acceleration up to the period of boost separation due to a misalignment of the boost;

(c) separating dispersion - a random impulsive velocity caused by shocks at boost separation.

The following table shows what contributions to the final scatter come from each of the causes.

Scatter in Lateral Velocity between 4 and 6 seconds after Firing

Measured in ft/sec root mean squared normal to the gathering line (elevation 19 degrees, bearing 355 degrees).

Origin of scatter	Left/right	Up/down
Total	71	47
Launching dispersion	24	23
Boost misalignment	47	23
Separating dispersion	47	34

Since these results are based on fifteen observations, it is not wise to place too much reliance on the precise values of the scatters. It appears that none of the three causes considered are negligible, but that the launching dispersion is the least.

One final test of dependence was made with estimates supplied by Mr. Jowett of GWTW, Aberporth, of the ground level wind speed across the line of fire. These showed that the horizontal displacement at 4 seconds after firing was correlated with cross-wind speed with a coefficient

$$-0.8.$$

This is sufficient to reduce the uncertainty of the left/right displacement X from an r.m.s. scatter of 139 feet to 84 feet by use of the regression line

$$X = -6.74\,W.$$

Here W ft/sec is the cross wind speed: only 12 observations of this were available.

The rounds tend to veer into wind as they leave the launcher and an allowance for the cross wind could reduce the horizontal dispersion by 40%. This high correlation is reduced by the uncertainty of the deviation at boost separation so that by the time the missile has been gathered, the degree of correlation between horizontal dispersion and wind speed is reduced to about 0.5.

One of the main items of interest concerning the dispersion of the rounds after launch and boost separation is the angular field of view which would be required by a telescope in order to include all the rounds. It is apparent from the preceding results that the spread of the missiles between 4 and 6 seconds after firing is roughly centred on the gathering line. This line at an elevation of 19 degrees and on the same bearing as the launcher is taken to be the optical axis of an imaginary telescope. Figs. 19, 20, 21 show where each of the rounds would have appeared in such a telescope at times of 4, 5 and 6 seconds after firing. These diagrams have been plotted from results obtained by dividing the lateral displacement of each round by its slant range at that time. It is worthy of comment that the left/right angular misalignment derived in this way differs by a factor equal to the cosine of the angle of elevation from the bearing of the round as measured from an alt-azimuth mounting. While the misalignment seen in the telescope is measured by the left/right displacement divided by the slant range to the missile, the bearing of the missile is the displacement divided by the ground range.

The slant ranges at 4, 5, 6 seconds are summarized in Figs. 22-24. They are measured like all the kine data from the guidance radar as origin. The launcher is situated roughly 600 feet in advance of the radar along the line of fire.

Slant Ranges of Missiles

Time after firing (secs)	4	5	6
Number of observations	16	16	15
Mean slant range (feet)	4420	5950	7440
R.m.s. scatter (feet)	240	230	240

These are rounded to the nearest ten feet.

The following table shows the angular misalignments of the individual rounds from which Figs. 19-21 were plotted. The last three columns quote the individual slant ranges of which the table above is a summary.

/Position

Position of Missile Referred to the Gathering Line

	Misalignment (mils)						Slant Range (feet)		
Time after Firing	4		5		6		4	5	6
Round Number	L/R	U/D	L/R	U/D	L/R	U/D			
2	47	26	52	30	56	25	4430	6000	7500
3	-40	48	-45	31	-46	19	3830	5410	6920
4	-32	10	-1	23	22	27	4470	5930	7350
5	2	-7	-4	-7	-7	-14	4150	5680	7200
7	16	-10	10	-8	3	-5	4350	5860	7270
8	-5	39	3	43	3	45	4520	6040	7530
9	-49	-15	-55	-10	X	X	4430	5950	X
10	-39	-9	-42	-9	-46	-11	4510	6010	7450
11	-30	-2	-35	-2	-43	-2	4590	6110	7570
12	-6	30	-9	36	-8	35	4820	6350	7820
13	-53	18	-61	29	-59	32	4770	6330	7850
14	35	-9	35	0	35	-1	4370	5920	7450
16	16	-18	16	-14	14	-13	4120	5620	7110
17	6	-23	1	-14	-2	-9	4330	5860	7360
18	12	-47	11	-46	13	-50	4430	5980	7500
19	-48	-17	-51	-14	-50	-19	4600	6160	7690

APPENDIX V

Dispersion of the Guidance Beam when the Missile has been Gathered

Bearing of Guidance Beam

Column	1	2	3	4	5	6	7	8	9	10	11	12	13
Round Number	Time After Firing (secs)	Missile				Optical Axis		F.T.	Beam-Riding Direction				
		Easting (feet)	Northing (feet)	Bearing (mils)	Misalignment (mils)	Bearing (mils)	w.r.t. F.T. (mils)	Bearing (mils)	Kine (mils)	Dials (mils)	Difference (mils)	Corrected dial (mils)	Bearing (mils)
2	7.0	494	8390	60.0	2.2	57.8	-	-	(55)	-36	(-91)	-	-
3	7.0	-391	7940	-50.2	-0.1	-50.1	-	-	(-55)	-153	(-98)	-	-
4	8.0	310	9400	33.6	3.2	30.4	-	-	(20)	-77	(-97)	-	-
5	6.0	-48	7100	-6.9	6.9	-13.8	-1.7	-12.1	-13.2	-117	-103.8	-12	-13
7	6.52	2	7500	0.3	4.0	-3.7	-0.8	-2.9	-4.0	-99	-95.0	-4	-4
8	7.8	-83	9495	-8.9	2.4	-18.3	-0.8	-17.5	-18.6	-115	-96.4	-20	-19
10	7.0	-392	8353	-47.8	-8.0	-39.8	-0.8	-39.0	-40.1	-146	-105.9	-41	-41
11	6.63	-350	8000	-44.6	-8.0	-36.6	-1.2	-35.4	-36.5	-142	-105.5	-37	-37
12	6.53	-86	8000	-11.0	1.3	-12.3	-1.2	-11.1	-12.2	-115	-102.8	-10	-11
13	7.92	-560	10090	-56.6	-0.2	-56.4	-1.2	-55.2	-56.3	-160	-103.7	-55	-56
14	6.8	300	8200	37.3	1.6	35.7	-1.2	36.9	35.8	-70	-105.8	35	35
16	6.0	96	6740	14.5	2.8	11.7	-1.5	13.2	12.1	-93	-105.1	12	12
17	4.21	20	4428	4.6	-3.1	7.7	-1.5	9.2	8.1	-99	-107.1	6	7
18	6.0	98	7202	13.9	-10.3	24.2	-1.5	25.7	24.6	-81	-105.6	24	24
19	10.01	-110	12844	-8.9	6.2	-15.1	-1.5	-13.6	-14.7	-118	-103.3	-13	-14

The determination of the direction of the radar beam when it is held steady for the purpose of gathering the missile is not a simple matter. The radar dial readings which are photographed between 18 and 25 times per second throughout the missile flight provide some indication. However, the dials can be read to only the nearest mil and may not be sufficiently accurate to give a reading correct to one mil. Furthermore, the zero directions of the dials are set up with reference to a telescope fixed to the dish, and not the direction of the radar beam. For these reasons, it was decided to establish some check on the direction of the radar beam.

The table above details the steps in deriving the bearing of the radar beam for each of the fifteen rounds which were still flying at 6 seconds from firing. The last column (13) shows the value chosen for the bearing. The five rounds which did not provide information over the gathering period were numbered 1, 6, 9, 15, 20. Of these, all except round 9 failed to achieve satisfactory boost separation: round 9 developed some intermittent fault as well as becoming lost to sight in cloud.

The independent check is achieved by using the determination of missile position by the kine theodolites. At some instant shown in column (1) when the dial records show the beam is steady, the corresponding easting and northing of the missile position are noted from the published data sheets. These are shown in columns 2 and 3. The quotient of these two distances equals the tangent of the bearing of the sight line from the radar set to the missile, shown in column 4 expressed in mils. At the same instant in time, the misalignment of the missile is noted in column 5, read by interpolation from the published records of the bore-sight camera which takes photographs at about the same speed as the dial camera.

The steps taken in forming the remainder of the table are illustrated by a diagram (Fig.49). Subtracting column 5 from column 4 gives the bearing of the optical axis used as zero for the bore-sight camera, referred to the line of fire, the datum direction used in the kine determinations (see column 6).

The method used for aligning the bore-sight camera and harmonizing it with the beam-riding direction is outlined in Appendix VII below. A more detailed study is contained in references 3, 4 and 5 where estimates of accuracy are quoted. The results required for the present task are listed in column 7, which shows the directions of the movable reference telescope with which the bore-sight camera was harmonized. These directions vary between sets of trials, and so have been referred to another reference telescope which is fixed rigidly and permanently to the radar dish. The difference of columns 6 and 7 is set out in column 8 and represents the bearing of the axis of the fixed telescope on the radar dish referred to the line of fire.

One further conclusion of Appendix VII is that the beam-riding direction of the SCR 584G as determined by many wing-aerial experiments is fixed relative to the radar dish and on a bearing 1.1 mils to the left of the axis of the fixed telescope. Thus 1.1 mils subtracted from column 8 gives column 9, the beam-riding direction of the radar dish referred to the line of fire 355 degrees, by way of the kine determination of missile position. This may be compared with the radar dial readings shown in column 10, all of which are measured from some radar north which corresponds roughly with true north. The differences between the kine determination of the beam-riding direction in column 9 and the dial determination in column 10 are listed in column 11. These should be constant apart from errors of measurement.

Because the records in the radar log book do not date back to rounds 2, 3, 4, it appears to be difficult to estimate the direction of the radar beam for these early rounds. This is particularly true since a different method was used for aligning the optical axis (the movable reference telescope), which might lead to angles of 10 mils or more between it and the beam-riding direction. By taking account of telemetry returns, it is possible to form some idea of where the beam-riding direction lay in relation to the optical axis of the bore-sight camera. The figures in brackets at the head of column 9 give these estimates. However, the resulting differences in column 11 deviate more from the average than appear likely and this throws suspicion on the observations. As the observations for rounds 2 and 3 appear to represent two of the largest dispersions observed, even ten mils error would cause a large error in the estimate of the scatter. For this reason, it was decided to ignore those observations for which no adequate check is available.

A similar discrepancy of about ten mils appears in the values in column 11 for the observations of rounds 7 and 8. Discounting these two rounds leaves ten estimates of the angle between radar north and the line of fire, and these yield an average of -104.9 mils with an r.m.s. scatter about the mean of 1.3 mils. This scatter appears to be about what could be expected from the accuracy of the separate steps in determining the difference values in column 11. With such a scatter as 1.3 mils, deviations of 9 mils are highly unlikely and it appears possible that both these dial readings are in error by 10 mils. How such an error could occur is uncertain, but it has been assumed that the possibility is plausible. Including the corrected versions for rounds 7 and 8 yields twelve observations, which have an average of -105.0 mils and an r.m.s. scatter of 1.3 mils.

If the radar zero were at true north, the average of the differences listed in column 11 would be -88.9 mils (5 degrees). In fact it appears from these observations that the radar north is 16 mils (almost one degree) to the right of true north.

The next column in the table above, column 12, is the sum of 105 mils and the values in column 10. This represents the dial readings corrected for zero error. Ideally these readings would equal the kine determinations listed in column 9. The best estimate of the true beam-riding direction is taken to be the average of the two determinations in columns 9 and 12, and this appears in column 13, rounded off to the nearest mil.

The 12 observations of the bearing of the radar beam when the missile is gathered give a mean and an r.m.s. scatter of

$$-10 \pm 26 \text{ mils}.$$

In an r.m.s. scatter of 26 mils, a mean of 10 mils is hardly significantly different from zero. Thus the distribution may be regarded as about zero mean with an r.m.s. scatter of 27 mils.

The distribution of the bearings is shown in Fig.25. It is obvious that it has considerable tails which make a gaussian curve inappropriate to fit. The reason for this is the peculiar dispersion of the round after launch and boost separation which was discussed above in Appendix IV. The tendency of the rounds to disperse to the left or right, or to fly comparatively undeviated, causes a wide scatter in the positions of the beam when it has gathered the missiles. It is difficult to divide the bearings of the beam in left, central and right groups for there is no obvious boundary. Further, comparison with the dispersion just before gathering commenced is not entirely satisfactory, since Fig.11 shows that round 19 was flying left, but Fig.25 shows that this round was gathered on a bearing close to the line of fire.

By comparison of the bearings of the gathering beam in Fig.25 and the left/right displacement of the rounds when gathering commences, it appears probable that bearings lying between ± 30 mils of the line of fire may be regarded as forming the central group. It is proposed to fit the observed distribution by three gaussian distributions covering left, mid and right flyers.

There are 3 left-flyers (rounds 10,11,13) with a mean and r.m.s. scatter of

$$-45 \pm 8 \text{ mils.}$$

There are 8 mid-flyers (rounds 5,7,8,12,16,17,18,19) with a mean and r.m.s. scatter of

$$-2 \pm 14 \text{ mils.}$$

There is one right flyer (round 14) with a bearing of

$$35 \text{ mils.}$$

From this fitted distribution, it may be deduced that 95% of the bearings of the radar beam when it has gathered the missile lie between ±55 mils (±3 degrees) of the line of fire. The actual observations show that round 13 was gathered on a bearing of -56 mils, and the remaining eleven rounds inside these bounds.

It is necessary to repeat the arguments above in dealing with the elevation of the radar beam when the missile has been gathered. The following table shows the main steps in the reasoning.

/Elevation

<u>Elevation of Guidance Beam</u>

Column	1	2	3	4	5	6	7	8	9	10	11	12	13
Round Number	Time after Firing secs	Missile				Optical Axis		F.T.	Beam-Riding Direction				
		Height H feet	Northing N feet	Elevation mils	Misalignment mils	Elevation mils	w.r.t. F.T. mils	Elevation mils	Kine mils	Dial mils	Difference mils	Corrected dial mils	Elevation mils
2	7.0	3063	8390	356.5	-11.1	367.6	-	-	(360)	370	(10)	-	-
3	7.0	2843	7940	350.3	-4.4	354.7	-	-	(357)	334	(-23)	-	-
4	8.0	3600	9400	372.6	1.0	371.6	-	-	(367)	388	(21)	-	-
5	6.0	2300	7100	319.0	-13.0	332.0	-11.0	343.0	331.4	342	10.6	331.7	332
7	6.52	2650	7500	345.9	9.7	336.2	-12.0	348.2	336.6	345	8.4	337.2	337
8	7.8	3720	9495	380.3	1.8	373.5	-12.0	390.5	378.9	389	10.1	381.2	380
10	7.0	2743	8353	323.2	-1.8	325.0	-12.0	337.0	325.4	329	3.6	322.4	323
11	6.68	2770	8000	339.6	-1.6	341.2	-12.0	353.2	341.6	345	3.4	339.6	341
12	6.53	3030	8000	368.8	-2.0	370.8	-12.0	382.5	371.2	377	5.8	371.6	371
13	7.92	3840	10090	370.5	-2.3	372.8	-12.0	384.8	373.2	378	4.8	373.8	373
14	6.8	2800	8200	335.2	0.0	335.2	-12.0	347.2	335.6	341	5.4	336.8	336
16	6.0	2230	6740	325.4	-6.5	331.9	-12.0	343.9	332.3	335	2.7	330.8	332
17	4.21	1426	4428	317.3	-5.4	322.7	-12.0	334.7	323.1	326	2.9	324.3	324
18	6.0	2098	7202	288.8	-4.8	293.6	-12.0	305.6	294.0	295	1.0	293.3	294
19	10.01	3940	12844	303.2	-11.0	314.2	-12.0	326.2	314.6	317	2.4	315.3	315

SECRET

The same instant of time as for determining the bearing of the missile was chosen for reading the kine-theodolite records. The heights and northings of the missiles are listed in columns (2) and (3) from which the angles of elevation can be calculated. These are expressed in mils in column (4). At the same instant of time shown in the column (1), the misalignment of the missile in the up/down direction is quoted in column (5), which has been read from the records of the dish camera photographs, with interpolation where necessary over 0.05 second interval. The elevation of the optical axis of the bore-sight dish camera is derived by subtracting column (5) from column (4): see column (6).

The next column (7) summarizes the notes in the radar log book which were taken in the process of harmonizing the movable reference telescope (the optical axis used for the firing) with the beam-riding direction as determined by a wing-aerial mounted on a mast. The values show the direction of the movable telescope on the radar dish (with which the bore-sight camera is harmonized) referred to a fixed telescope (abbreviated to F.T. in the table above), which is left static relative to the radar dish. Column (8) shows the difference of columns (6) and (7) and represents the elevation of the axis of the fixed telescope above horizontal, the datum on which the kine observations are based. It is shown in Appendix VII that the beam-riding direction of the radar set as determined by many wing aerial experiments lies at an elevation 11.6 mils below that of the fixed telescope. This determines the figures in column (9) which show the elevation of the beam-riding direction in each firing, estimated by way of the kine-theodolite plots. Column (10) contains the corresponding dial readings and the next column (11) shows the difference between the dial readings and the kine determination.

As above in dealing with the bearing of the beam, the information concerning the early rounds 2, 3, 4 seems too conflicting to lead to a reliable estimate. These rounds have been dismissed as providing no information towards the following discussion.

If there were no drift of the zero of the radar dial, the angle represented by the values in column (11) should be a constant equal to the dial reading when the beam-riding direction is horizontal. The figures are subject to experimental errors due to the roundabout determination, which may be expected to contribute an r.m.s. scatter about the mean of 1.5 mils, approximately the same as the corresponding scatter in the determination of the bearing zero error. However, the values in column (11) of the table above lead to a mean and an r.m.s. scatter of

$$5.1 \pm 3.0 \text{ mils.}$$

This scatter is roughly twice what would be expected and calls for some attempt to reduce it.

Inspection of the figures in column (11) reveals a definite trend from a value about 10 mils for the early rounds to a value about 3 mils for the late rounds. There is not enough evidence to support a suggestion that the dial zero has drifted with time. However it appears reasonable to try to correlate the figures with the month in which the round was fired. This leads to a correlation coefficient of 0.87 which is sufficiently high to enable the scatter to be halved by fitting the appropriate regression line. Accordingly, the following straight line was fitted to the elevation zero values in column (11): the fitted value is

$$(10.3 - 1.23\,n) \text{ mils}$$

where n is the number of months later than October 1951 that the firing took place. The following table compares the actual estimates of the elevation zero bias and the fitted values.

Smoothing the Elevation Zero Observations

Round Number		5	7	8	10	11	12	13	14	16	17	18	19
Months since	10-51	0	2	2	3	4	4	5	5	5	7	7	7
Observation	mils	10.6	5.4	10.1	3.6	3.4	5.8	4.8	5.4	2.7	2.9	1.0	2.4
Fitted value	mils	10.3	7.8	7.8	6.6	5.4	5.4	4.2	4.2	4.2	1.7	1.7	1.7

This can hardly be used as evidence that the elevation zero of the radar dial drifted by 9 mils in a period of seven months. Similar high correlation would exist between the observations and the number of the round in the trial, although there is no logical connection between them. However, some unexplained cause has produced a trend which is too obvious to neglect.

The differences of the smoothed values of the elevation zero bias and the dial readings in column (10) of the main table supply the elevations of the radar beam corrected for zero error. These corrected dial readings are listed in column (12). The estimate of the true beam elevation has been taken as the average of columns (9) and (12) and this is shown in column (13) rounded off to the nearest mil since the accuracy is no better than this.

The 12 observations of the elevation of the radar beam when the missile has been gathered give a mean and r.m.s. scatter of

$$338 \pm 24 \text{ mils.}$$

The distribution of elevations is shown in Fig.26. The mean elevation of 338 mils almost exactly equals 19 degrees.

A comparison with Fig.14 which displays the up/down displacement of the missile at 6 seconds after firing, roughly at the commencement of gathering, confirms the division of the set of 12 rounds into three groups comprising those which flew high, middle and low. It appears reasonable to fit the observed distribution shown in Fig.26 by three gaussian distributions centred on each of the three groups.

There are 3 high-flying rounds (numbered 8,12,13) which were gathered at elevations with a mean and r.m.s. scatter of

$$375 \pm 4 \text{ mils.}$$

There are 8 mid-flying rounds (numbered 5,7,10,11,14,16,17,19) which were gathered at elevations with a mean and an r.m.s. scatter of

$$330 \pm 8 \text{ mils.}$$

One round (number 18) flew low and was gathered at an elevation of

$$294 \text{ mils.}$$

According to the fitted distribution, 90% of the rounds are gathered at an elevation of 309 mils or higher above the horizon; this is a quadrant elevation of 17.4 degrees. The actual observations show that eleven rounds out of the twelve were gathered at an elevation above 309 mils. Also according to the fitted distribution, 95% of the rounds are gathered between elevations of 382 mils and 294 mils, i.e. 338 ± 44 mils. The mean

elevation of 338 mils (19 degrees) above horizontal defines the elevation of the gathering line, the mean direction of the guidance beam when it has been held steady for gathering the missile. The bearing of the gathering line is the same as that of the launcher (355 degrees).

The following table shows the times after firing when the elevation and the bearing of the radar beam became steady so that the missile could recover into a stationary beam. They have been taken from the published records of the radar dial readings.

Times After Firing to Steady Guidance Beam

Round Number		2	3	4	5	7	8	9	10
Time after Firing (secs)	Elevation steady	6.53	6.58	7.93	6.12	6.38	7.61	7.33	6.25
	Bearing steady	5.[illegible]2	5.20	7.78	5.44	5.41	4.57	6.96	6.58
	Beam steady	6.53	6.58	7.92	6.12	6.38	7.61	7.33	6.58
Round Number		**11**	**12**	**13**	**14**	**16**	**17**	**18**	**19**
Time after Firing (secs)	Elevation steady	5.76	5.88	6.25	6.43	5.43	3.92	5.13	8.87
	Bearing steady	6.76	5.58	7.83	6.63	4.47	3.08	3.39	9.28
	Beam steady	6.76	5.88	7.83	6.63	5.43	3.92	5.13	9.28

The times shown in the above table are likely to differ from those published elsewhere, since opinions vary as to the exact time at which the beam becomes steady. The dial readings are correct only to the nearest mil, and are liable to show jumps of one mil in long series of steady values. For this reason, the beam has been considered steady when the dial readings reach a value and remain within one mil from that which appears afterwards to be the steady value. The time quoted is correct to about 0.05 second.

Four rounds (numbered 1,6,15,20) failed to fly long enough for the beam to settle on them.

The 16 observations of the time when the elevation of the beam becomes steady have a mean and an r.m.s. scatter of

$$6.40 \pm 1.13 \text{ seconds}.$$

A value has been quoted for round 3 although the beam never settled for longer than one second on any particular value, but moved upwards eventually at about 3 mils/sec.

The 16 observations of the time when the bearing of the beam becomes steady have a mean and r.m.s. scatter of

$$5.92 \pm 1.59 \text{ seconds}.$$

For five rounds (numbered 10,11,13,14,19) the elevation of the beam was steady before the bearing. For the remaining eleven rounds considered in the table, the bearing became steady before the elevation. This is to be expected since the beam swings through an angle in elevation almost ten times that in bearing while following the round off the launcher.

The 16 observations of the time when the beam becomes steady have a mean and an r.m.s. scatter of

$$6.62 \pm 1.21 \text{ seconds}.$$

The distributions of these times are shown in Figs. 28, 29 and 30. They appear to have long tails compared with a gaussian distribution.

For some purposes, the time of 3.92 seconds when the beam became steady for round 17 is unrepresentative. The gathering of round 17 was more by accident than by the normal technique, since the guidance beam became disconnected from the optical tracker through a switching fault. If this observation is disregarded, the 15 observations of the time when the beam becomes steady have a mean and an r.m.s. scatter of

$$6.80 \pm 1.03 \text{ seconds.}$$

If it is assumed that a normal gaussian distribution fits the observations, 95% of the times after firing when the beam becomes steady lie between

$$4.75 \text{ and } 8.65 \text{ seconds.}$$

Of the slant ranges of the missile from the guidance set when the beam becomes steady (see table below), fifteen observations are available, since no records were published for round 9. If the observation for round 17 is discounted for the reasons stated above, the remaining 14 observations of the slant range of the missile when the beam becomes steady have a mean and an r.m.s. scatter of

$$8900 \pm 1600 \text{ feet.}$$

These observations of ranges have been read from the records of radar range published after each firing. The radar ranges were not published for round 2 and this observation has been interpolated from the kine-theodolite records.

<u>Range of Missile when Guidance Beam became Steady</u>

Round Number	2	3	4	5	7	8	9	10
Slant range (thousands of feet)	8.3	8.2	10.4	8.0	8.2	10.0	-	8.5
Round Number	**11**	**12**	**13**	**14**	**16**	**17**	**18**	**19**
Slant range (thousands of feet)	9.1	8.0	10.8	8.7	6.7	4.4	6.6	12.9

APPENDIX VI

Velocity and Slant Range of Missile During the Beam Programme

Velocity of Missile 10-25 seconds after Firing (ft/sec)

Time after Firing (secs) \ Round Number	2	3	4	5	8	11	13	14	16	17	18	19
10	1378	1320	1321	1431	1340	1358	1392	1474	1310	1440	1500	1350
15	1306	-	1343	-	1283	1342	1285	1404	1160	1300	1540	1270
20	1397	-	1412	-	1275	1257	1178	1411	1020	1190	1530	-
25	1277	-	1418	-	1263	1065	1158	1428	1000	-	-	-
30	1088	-	1184	-	1110	-	910	1185	960	-	-	-

No records are available for rounds 1, 6, 15 and 20 which failed before or soon after boost separation.

No records are available for rounds 7 and 9 which failed soon after gathering at the start of the programme period.

Rounds 10 and 12 are unrepresentative since the propulsion failed.

The speeds in the table above are flight path velocities of the missiles, calculated by interpolation from the published records. Since the trajectory of the missile is almost directly away from the guidance radar, the speeds do not differ much from those measured by the doppler receiving set, which determines the rate of charge of the slant range.

The distributions of these missile speeds are displayed by histograms in Figs. 31-35.

The following table summarizes the observations above by quoting the mean and r.m.s. scatter at each of the times.

Time after firing (secs)	10	15	20	25	30
Number of observations	12	10	9	7	6
Mean speed (ft/sec)	1385	1323	1287	1230	1073
R.m.s. scatter (ft/sec)	61	94	143	153	105

After about 25 seconds from firing, the missile speed drops away rapidly at roughly 40 ft/sec^2 as the sustainer motor ceases to thrust. The following table shows the times at which the motor thrust ceased for the rounds which were still flying correctly. Round 11 appears suspect as the speed dropped about 18.5 seconds after firing, and it is doubtful if the motor was working correctly. The instant at which the thrust ceases is most easily measured from the discontinuity in gradient on the record of missile speed against time.

Time when Motor Thrust Ceases

Round number	2	4	8	13	14	16
Time after firing (secs)	24.0	24.0	25.8	26.5	24.5	29.0

These six observations of the time after firing when the motor ceases to thrust give a mean and r.m.s. scatter of

$$25.7 \pm 1.7 \text{ seconds.}$$

The distribution is shown in Fig.43.

Time when Speed Drops to 1200 and 1100 feet per second

Round Number		2	4	8	11	13	14	17
Time after firing (secs) when speed drops below	1200 ft/sec	26.4	29.6	27.7	21.6	17.2	29.0	18.7
	1100 ft/sec	29.1	32.0	30.2	24.1	26.1	30.5	-

The table above shows when the flight path velocity of the missiles determined from the kine-doppler records fell below 1200 and 1100 ft/sec. The seven rounds 1, 3, 5, 6, 7, 15, 20 broke up early in flight while round 9 was faulty and no records were published. No records are available for round 18 or for round 17 at the speed of 1100 ft/sec. The four rounds 10, 12, 16 and 19 are unrepresentative since the motor either failed to light or did not thrust correctly.

The distributions of the observations are shown in Figs. 44 (a) and (b). The scatter on the time when the missile speed falls to 1200 ft/sec is so great that it appears unreasonable to fit any distribution until there are a greater number of observations. Rounds 13 and 17 were on climbing courses which accounts for the early loss of speed. The motor in round 11 does not appear to have worked perfectly. The rounds representative of a straight flying or steadily traversing missile are four numbered 2, 4, 8, 14.

The scatter on the time when the speed falls to 1100 ft/sec is rather less than for 1200 ft/sec. The same remarks as above apply except that there is a little more justification for analysing the overall scatter.

The 6 observations of the time after firing when the missile speed drops below 1100 ft/sec have a mean and an r.m.s. scatter of

$$28.7 \pm 2.7 \text{ seconds.}$$

Between 10 and 25 seconds after firing, the missile is directed by the guidance beam on the programme set for the trial. The lower time limit is set by the gathering of the missile. The upper limit is set by the duration of the motor, which is necessary to sustain the speed around the value for which the control system was designed.

It is possible to approximate to the mean velocities over this programme interval by a velocity which represents a constant deceleration. The straight line which best fits the four determinations at 10, 15, 20, 25 seconds in the sense of total least squared deviation is

$$(1480 - 10t) \text{ ft/sec}$$

where t is the time in seconds after firing.

The mean speeds and the fitted speeds are shown in the following table.

Time after firing (secs)	10	15	20	25
Average speed (ft/sec)	1385	1323	1287	1230
Fitted speed (ft/sec)	1380	1330	1280	1230

Since there are only small discrepancies between the average speeds and the fitted speeds at each of the four times, it is reasonable to regard the actual observed speeds as scattered about the fitted speed curve. These scatters too may be smoothed since they appear to be roughly proportional to the time after firing.

The following table summarizes the information about the missile speed between 10 and 25 seconds from firing, after it has been smoothed.

Time after firing (secs)	10	15	20	25
Average speed (ft/sec)	1380	1330	1280	1230
R.m.s. scatter (ft/sec)	64	96	128	160

The average missile appears to decelerate slowly at 10 ft/sec^2 between the times 10 and 25 seconds after firing, during which period the speed falls from 1380 ft/sec to 1230 ft/sec. This has been represented as a graph of missile speed against time after firing in Fig.41.

Slant Range of Missile 10-25 seconds after Firing, measured in thousands of feet

Time after Firing (secs) \ Round Number	2	4	8	11	13	14	16	17	18	19
10	13.2	12.8	13.2	13.6	13.9	13.7	13.1	13.5	13.9	13.9
15	19.9	19.7	19.8	20.3	20.6	20.9	19.2	20.5	21.6	20.5
20	26.4	26.3	26.1	26.6	26.4	27.6	24.5	26.7	29.3	25.9
25	32.9	33.5	32.3	32.8	32.3	34.9	29.7	32.6	36.7	32.3
30	38.7	40.0	-	-	37.3	41.4	34.6	38.1	-	-

These slant ranges are measured from the guidance radar, rounded off to the nearest hundred feet. Of the ten rounds for which no observations are quoted above, rounds 1, 6, 15, 20 all failed about the time of boost separation. Round 9 suffered from some intermittent fault and no records were published. Rounds 3, 5, 7 all failed soon after the start of the programme. The remaining two rounds numbered 10 and 12 have been discounted since the sustainer motors failed to ignite.

The distributions of these slant ranges are displayed as histograms in Figs. 36-40. From these distributions it is possible to make one or two remarks. Round 4 suffered a bad boost separation which caused high drag and low speed. This is noticeable up to 10 seconds after firing, but the motor appears to have supplied high thrust and the missile passed the average performance in range after 20 seconds from firing. Rounds 14 and 18 also had exceptionally powerful motors. Round 18 flew on an unusually low trajectory, but this should have affected the slant range up to 30 seconds from firing by not more than 200 feet. Although rounds 13 and 17 flew on climbing courses, they remained very close to the average performance in slant range, but the velocity at 25 seconds was below average. Round 16 appears to have suffered from an unusually poor motor.

The following table shows for each of the five times 10,15,20,25,30 seconds after firing the mean slant range and the r.m.s. scatter averaged over the missiles.

Time after firing (secs)	10	15	20	25	30
Number of observations	10	10	10	10	6
Mean slant range (K feet)	13.48	20.30	26.58	33.00	38.35
R.m.s. scatter (K feet)	0.37	0.65	1.17	1.74	2.14

In a similar way to the approximation of the mean velocities by a velocity with constant deceleration, the mean slant ranges may also be approximated to a slant range which represents constant deceleration. This amounts to fitting a quadratic expression in t (the time in seconds after firing) to the calculated mean slant ranges shown in the table above. Since the mean velocity of the missiles has been approximated by the expression

$$1480 - 10\,t \text{ ft/sec}$$

it follows that the slant range must be of the form

$$S_o + 1480\,t - 5\,t^2 \text{ feet}$$

where S_o is a constant to be determined. A least squares fit to the value of S_o using all the forty results for the slant ranges between 10 and 25 seconds after firing leads to

$$S_o = -928 \text{ feet.}$$

If this is rounded to the nearest hundred feet, the fitted average slant range of the missiles is

$$-900 + 1480\,t - 5\,t^2 \text{ feet}$$

$$= 13400 + 1380\,(t-10) - 5\,(t-10)^2 \text{ feet}$$

valid for t between 10 and 25 seconds.

The following table summarizes the information about the slant range of the missiles over the programme period between 10 and 25 seconds after firing.

Time after firing (secs)	10	15	20	25
Smoothed average slant range (K feet)	13.4	20.2	26.7	33.0
R.m.s. scatter (K feet)	0.4	0.7	1.2	1.7

This has been represented on a graph of slant range against time in Fig.42.

APPENDIX VII

Beam-Riding Direction of the Guidance Radar

The observations which form the basis of this appendix were taken in the process of harmonizing the dish camera with the beam-riding axis of the radar dish. The procedure has been described fully elsewhere (references 3,5) and the method is merely outlined below.

The first step is to harmonise a movable reference telescope on the radar dish with the beam-riding direction. The dish is pointed at a wing-aerial mounted on a mast in front of the radar building, while the radar is transmitting and the spinner nutating. The dish is aligned carefully so that the modulation on the signal received at the wing aerial is reduced to zero. Since the dish is moved by velocity control and the backlash amounts to almost 2 mils, this has to be completed often by pushing the dish by hand. When this alignment is satisfactory, the wing-aerial lies on the beam-riding direction of the radar dish. The movable reference telescope is adjusted so that it points at the wing-aerial, with an offset allowance for the parallax between the movable telescope and the centre of the dish. Viewed from behind, the movable telescope is high and left of the centre of the dish, so that readings of the wing-aerial direction on the graticule of the movable telescope need added corrections of 0.75 mil in elevation and -4.1 mils in azimuth. The estimated accuracy of harmonizing the movable reference telescope with the beam-riding direction has an r.m.s. scatter of 0.75 mils (reference 5).

The dish camera records are harmonised with the movable reference telescope by means of a few pictures taken at the start of each firing. The radar dish is pointed at a sighting board on which the relative positions of the movable reference telescope, the fixed reference telescope and the dish cameras are marked as a means of eliminating parallax. An operator views the movable telescope mark on the sighting board through the movable telescope and by commands to the radar operator and by manual adjustment, lays the dish so that the mark appears on the cross wires. The dish camera then shoots several pictures of the sighting board. The pictures of the dish camera mark are used as a zero when the remaining pictures on the spool are assessed. The estimated accuracy of laying the reference telescope on the sighting board has an r.m.s. scatter of 0.9 mil (reference 5). Compared with this, errors in reading the dish camera records and registering the camera marker are less than one fifth and so negligible. As a periodic check that the movable telescope has not been knocked out of true, readings are taken to compare it with a fixed reference telescope which is left permanently static on the radar dish. This fixed reference telescope has merely cross wires in its field of view instead of the graticule marked in the movable telescope. The fixed telescope is laid on its mark on the sighting board by moving the radar dish and then the displacement of the movable telescope mark is read on the movable telescope graticule. The divisions on this graticule are one mil apart and it is difficult to achieve accuracy in reading better than ½ mil. As with laying the movable telescope on its mark, the accuracy expected in this comparison of reference telescopes would be an r.m.s. scatter of 0.9 mil.

The following table lists observations which were copied out of the SCR 584G log book from the time of its inception to the date of writing. They are not corrected for the parallax error due to the short distance (265 feet) of the wing-aerial from the guidance radar.

BEAM RIDING DIRECTION DETERMINED FROM WING-AERIAL EXPERIMENTS

Date 1951	Elevation (mils) M.T. w.r.t. F.T.	Elevation (mils) W.A. w.r.t. M.T.	Elevation (mils) W.A. w.r.t. F.T.	Bearing (mils) M.T. w.r.t. F.T.	Bearing (mils) W.A. w.r.t. M.T.	Bearing (mils) W.A. w.r.t. F.T.
17-9	-10.0	-0.5	-10.5	-2.0	5.0	3.0
25-9	-10.0	-1.0	-11.0	-2.0	2.5	0.5
25-9	-10.0	0.0	-10.0	-2.0	2.5	0.5
27-9	-10.0	-1.0	-11.0	-2.0	5.0	3.0
27-9	-10.0	-1.0	-11.0	-2.0	5.0	3.0
28-9	-10.0	-2.0	-12.0	-2.0	4.0	2.0
28-9	-10.0	-2.0	-12.0	-2.0	5.0	3.0
1-10	-10.0	-2.0	-12.0	-2.0	4.0	2.0
	Movable telescope altered					
1-10	-11.5			-1.5		
17-10	-11.0	-1.5	-12.5	-2.0	3.5	1.5
22-10	-10.5	-1.0	-11.5	-2.0	4.5	2.5
24-10	-10.5	-1.0	-11.5	-1.5	4.25	2.75
24-10	-11.0	-1.0	-12.5	-1.5	4.5	3.0
29-10	-11.0	-1.0	-12.0	-1.5	4.0	2.5
30-10	-11.0	-0.5	-11.5	-1.5	4.5	3.0
31-10	-11.0	-1.0	-12.0	-1.5	4.5	3.0
1-11	-11.5	-1.5	-13.0	-1.5	4.0	2.5
2-11	-11.0	-1.5	-12.5	-1.5	4.5	3.0
5-11	-10.5	-1.5	-12.0	-2.0	4.5	2.5
7-11	-11.0	-1.0	-12.0	-1.5	4.5	3.0
11-11	-11.0	-1.0	-12.0	-2.0	7.0	5.0
	Movable telescope altered					
11-11	-10.5	-1.0	-11.5	0.5	4.0	4.5
12-11	-10.5	-1.5	-12.0	0.5	5.5	6.0
6-12	-11.0	-1.0	-12.0	0.5	3.0	3.5
7-12	-11.0	-2.0	-13.0	0.5	2.5	3.0
	Movable telescope altered					
10-12	-12.0	-1.0	-13.0	-0.5	4.0	3.5
11-12	-12.0	-1.0	-13.0	-0.5	4.0	3.5
12-12	-12.0	-0.5	-12.5	-0.5	4.0	3.5

Date 1952	Elevation (mils) M.T. w.r.t. F.T.	Elevation (mils) W.A. w.r.t. M.T.	Elevation (mils) W.A. w.r.t. F.T.	Bearing (mils) M.T. w.r.t. F.T.	Bearing (mils) W.A. w.r.t. M.T.	Bearing (mils) W.A. w.r.t. F.T.
15-1	-12.0	-0.25	-12.25	0.0	4.0	4.0
16-1		-1.0	-13.0		4.0	4.0
18-1		-1.0	-13.0		4.0	4.0
	-12.0	-0.5	-12.5	-1.0	4.5	3.5
23-1	-12.0	-0.5	-12.5	-1.0	4.0	3.0
25-1	-12.0	-1.0	-13.0	-1.0	4.5	3.5
26-1	-12.0	-1.0	-13.0	-1.0	4.0	3.0
28-1	-12.0	-1.0	-13.0	-1.0	4.0	3.0
29-1	-12.0	-1.0	-13.0	-1.0	4.0	3.0
1-2	-12.0	-1.0	-13.0	-1.0	4.0	3.0
4-2	-12.0	-1.0	-13.0	-1.0	4.2	3.2
7-2		-1.0	-13.0		3.5	2.5
8-2	-12.0	-1.0	-13.0	-1.0	3.5	2.5
	New reference generator shaft bearings					
12-2	-12.0	-1.5	-13.5	-0.5	3.5	3.0
13-2		-1.0	-13.0		3.5	3.0
14-2		-0.5	-12.5		3.0	2.5
	Movable telescope altered					
15-2	-12.0	0.0	-12.0	-1.5	4.5	3.0
19-2	-12.0	-0.5	-12.5	-1.0	4.5	3.5
24-2	-12.0	-0.5	-12.5	-1.0	4.0	3.0
26-2	-12.0	-0.5	-12.5	-1.0	4.5	3.5
27-2	-12.0	-0.5	-12.5	-1.0	4.5	3.5
5-3	-12.0	-0.5	-12.5	-1.0	4.0	3.0
10-3	-12.0	-0.5	-12.5	-2.0	4.5	2.5
11-3		-0.5	-12.5		4.5	2.5
12-3		-0.5	-12.5		4.5	2.5
	Dish and spinner stripped					
7-5	-12.0	-0.5	-12.5	-1.5	4.5	3.0
9-5	-12.0	-0.5	-12.5	-1.5	4.5	3.0
15-5		-0.5	-12.5		4.5	3.0
16-5		-0.5	-12.5		4.5	3.0
21-5		-0.5	-12.5		4.5	3.0
23-5	-12.0	-0.5	-12.5	-1.5	4.5	3.0
27-5	-12.0	-0.5	-12.5	-1.5	4.5	3.0

F.T. means fixed reference telescope.

M.T. means movable reference telescope.

W.A. means the wing-aerial direction.

Figs. 47 and 48 show the distributions of all the observations (in elevation and bearing) of the direction of the movable telescope referred to the axis of the fixed reference telescope. The following table summarizes the measurements of this angle. They are grouped into six periods during which the movable telescope was left static.

<u>Inclination of Fixed Relative to Movable Telescope</u>

First date	17.9.51	1.10.51	11.11.51	10.12.51	15.2.52	7.5.52
Last date	1.10.51	11.11.51	7.12.51	14.2.52	12.3.52	27.5.52
Number of observations	8	13	3	13	7	4
Mean elevation (mils)	10.0	10.96	10.83	12.0	12.0	12.0
R.m.s. scatter (mils)	0	0.31	0.24	0	0	0
Mean bearing (mils)	2.0	1.65	-0.5	0.81	1.21	1.5
R.m.s. scatter (mils)	0	0.23	0	0.31	0.36	0

It is difficult to estimate how many of these records are independent observations, and how many are merely copies of the last entry in the log book. Counting all entries as independent gives a total of 48 observations and this suggests an r.m.s. accuracy of

0.18 mils in azimuth

0.25 mils in elevation.

Even if only a quarter of these observations were actually independent, the r.m.s. accuracy would be better than half a mil in both bearing and elevation, which suggests that the estimate of 0.9 mil is unduly pessimistic. The operations covered by this estimate of accuracy are those of laying the radar dish on a fixed mark, and then reading the graticule in the movable reference telescope.

At the same time as the check on the alignment of the movable telescope, it is usual to carry out a wing-aerial experiment as described at the start of the appendix, to determine how far the movable telescope points away from the beam-riding axis. This experiment may occur more frequently, as it is normally carried out every time an RTV1 is likely to be fired. The large table above shows the results of sixty of these experiments. Addition of the wing-aerial direction relative to the movable telescope and the movable telescope direction relative to the fixed reference telescope gives the angles between the wing-aerial direction and the fixed telescope. These observations are also listed in the table and may be used to find whether the beam-riding direction varies relative to the radar dish, since the wing-aerial direction (when the signal modulation is zero) is related to the beam-riding direction through a fixed correction for parallax.

The distributions of the observations of elevation and bearing are shown in Figs. 45 and 46.

The 60 observations of the elevation angle between the wing-aerial direction and the axis of the fixed telescope have a mean and an r.m.s. scatter of

$$-12.33 \pm 0.67 \text{ mils.}$$

The 60 observations of the bearing angle between the wing-aerial direction and the axis of the fixed reference telescope have a mean and an r.m.s. scatter of

$$3.01 \pm 0.82 \text{ mils.}$$

Taking these observations involves twice laying the dish and reading the graticule in the movable telescope. Thus these scatters are below the expected magnitude (1.2 mils) suggested by reference 5. They agree with the value (0.7 mil) derived from the accuracy of half a mil for each operation proposed above as a result of analysing the observations of the movable telescope relative to the fixed telescope. The scatters suggest that the beam-riding direction as determined by the wing-aerial experiment is invariant relative to the radar dish. Deviations of the order of 0.2 mil would not be apparent in the above results.

Corrected for the parallax between the wing-aerial direction and the beam-riding direction, as described at the start of the Appendix, the beam-riding direction is at

an elevation of -11.6 mils

and a bearing of -1.1 mils

relative to the axis of the fixed reference telescope. This result was used in Appendix V.

The small table above shows that during the period under review, the movable telescope was altered on five occasions. The six determinations of the direction of the movable reference telescope show that it pointed at

an elevation of -11.3 ± 0.8 mils

and a bearing of -1.1 ± 0.8 mils

relative to the axis of the fixed reference telescope. Each adjustment was intended to harmonize the movable telescope with the beam-riding direction and comparison of the mean direction of the movable reference telescope with the beam-riding direction of the radar dish shows that they hardly differ significantly. Thus the accuracy of harmonizing the movable reference telescope with the beam-riding direction has a root mean squared scatter of 0.8 mil in both azimuth and elevation.

FIG. I

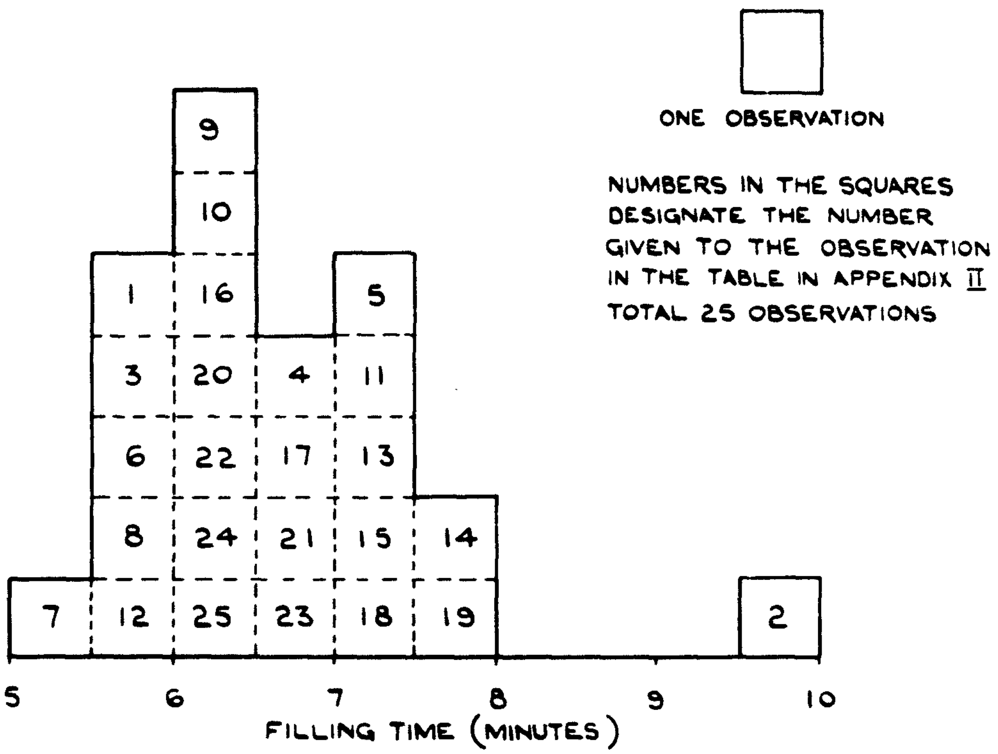

FIG.I VARIATION OF FILLING TIME OF LIQUID OXYGEN IN MISSILE TANK.

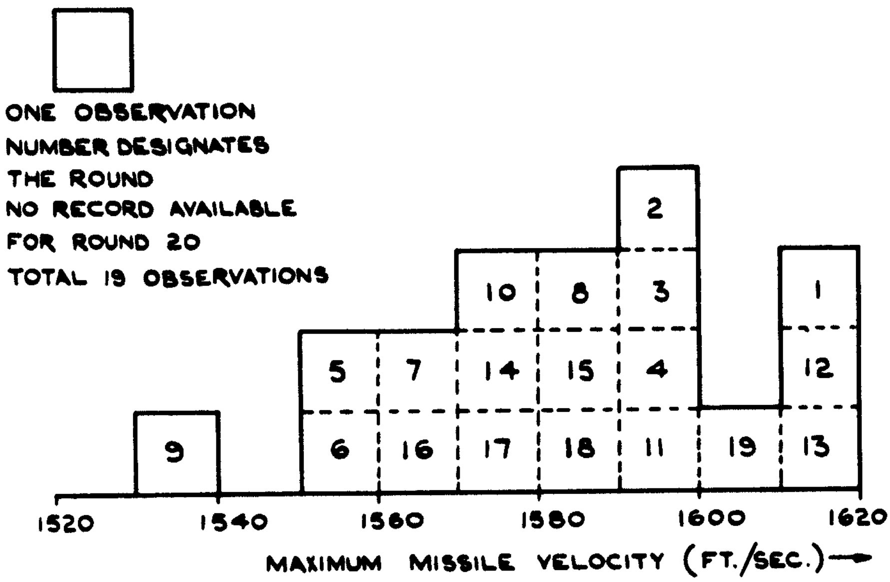

FIG. 2 MAXIMUM MISSILE VELOCITY.

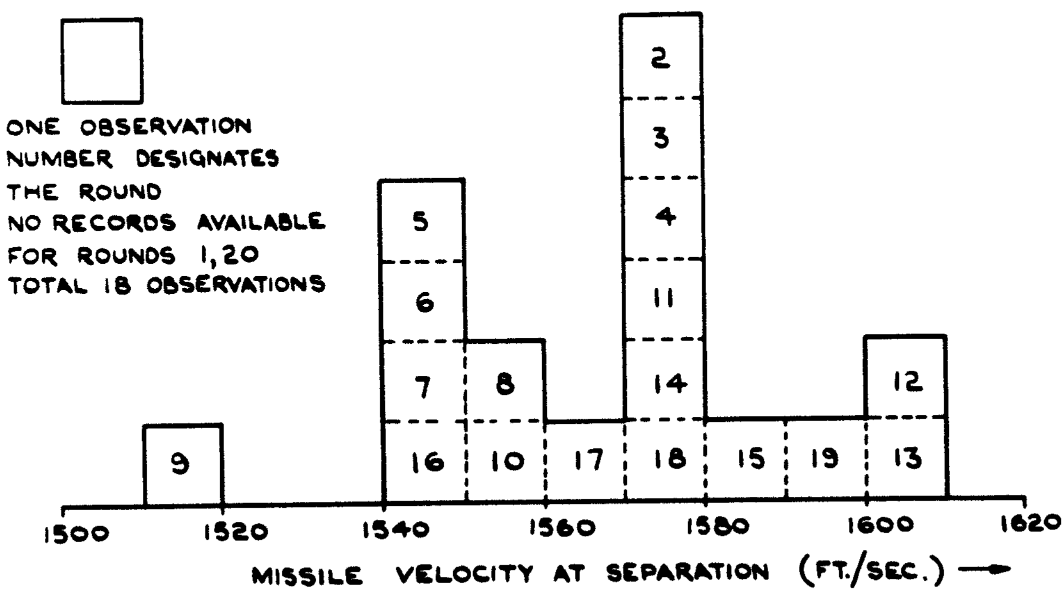

FIG. 3 MISSILE VELOCITY AT BOOST SEPARATION.

FIG. 4 & 5

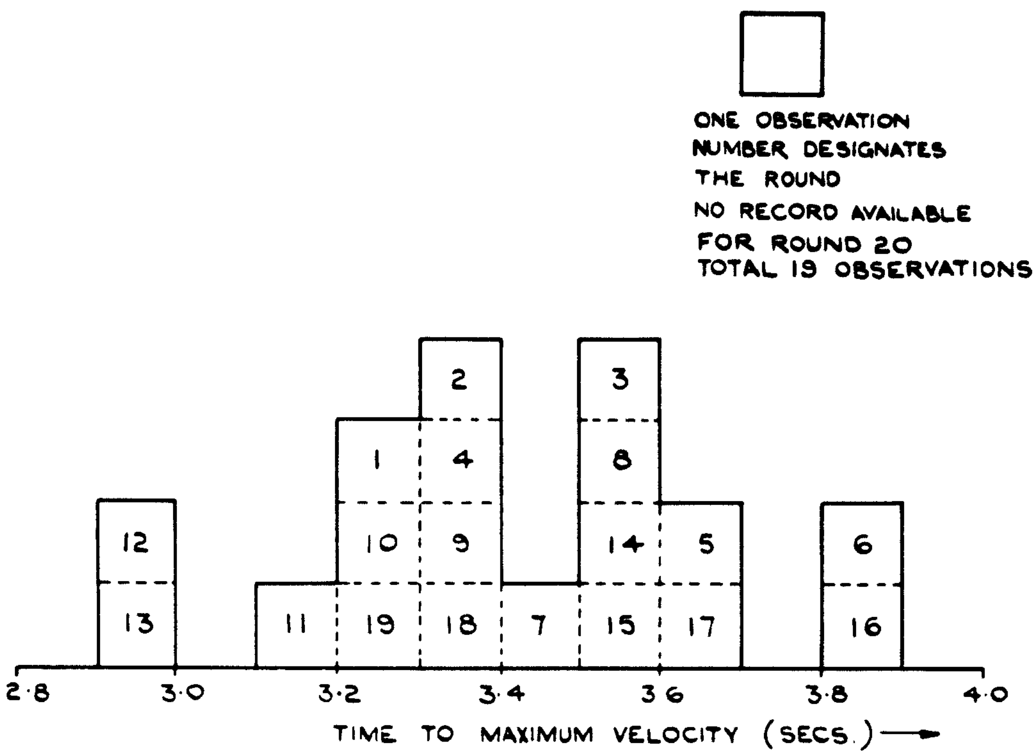

FIG. 4 TIME FROM FIRING OF MAXIMUM VELOCITY.

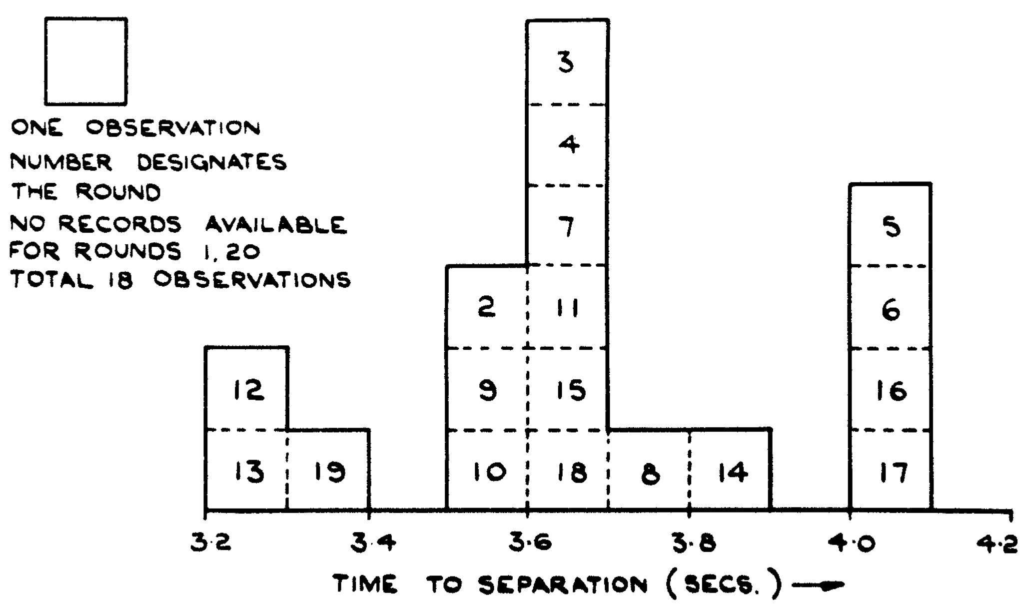

FIG. 5 TIME FROM FIRING OF BOOST SEPARATION.

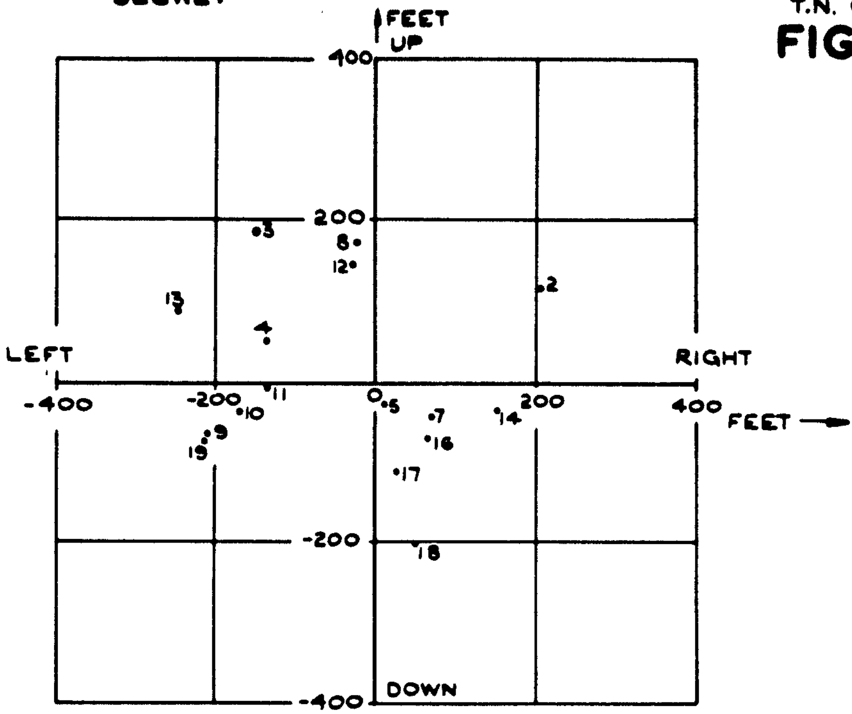

FIG. 6 POSITION OF ROUND 4 SECONDS AFTER FIRING.

NUMBER DESIGNATES THE ROUND
NO RECORDS FOR ROUNDS 1, 6, 15, 20.
BASED ON MEASUREMENTS NORMAL TO A LINE FROM THE GUIDANCE RADAR ON BEARING 355 DEGREES, ELEVATION 19 DEGREES

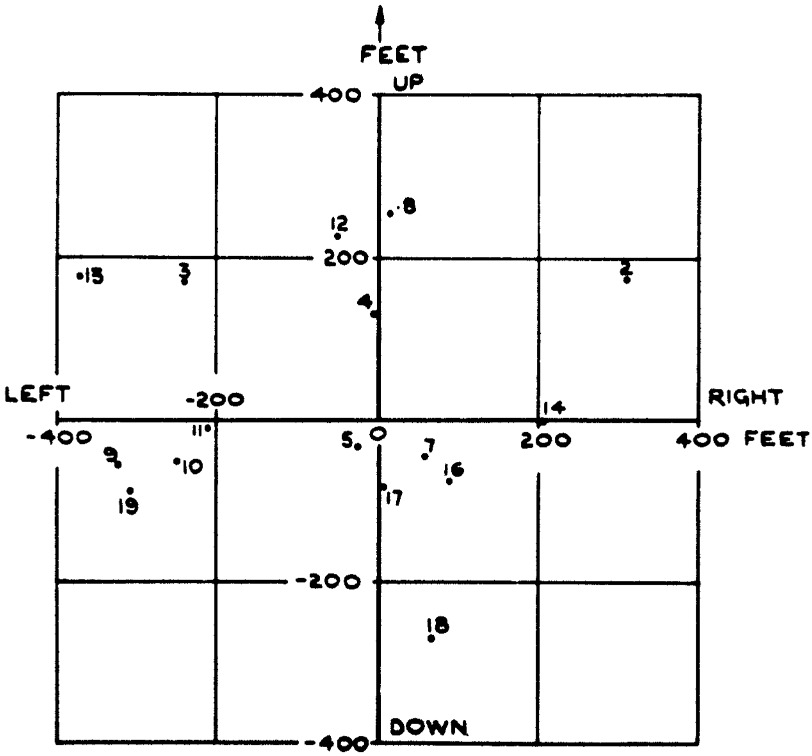

FIG. 7 POSITION OF ROUND 5 SECONDS AFTER FIRING.

NUMBER DESIGNATES THE ROUND.
NO RECORDS FOR ROUNDS 1, 6, 15, 20.
BASED ON MEASUREMENTS NORMAL TO A LINE FROM THE GUIDANCE RADAR ON BEARING 355 DEGREES, ELEVATION 19 DEGREES

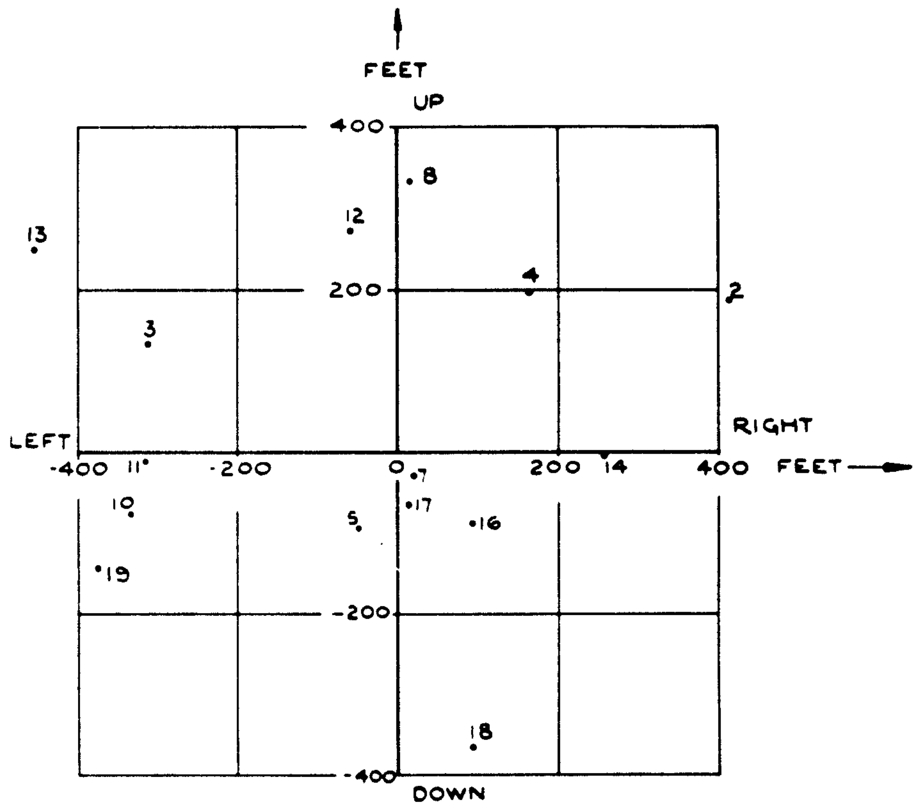

FIG. 8 POSITION OF ROUND 6 SECONDS AFTER FIRING.

NUMBER DESIGNATES THE ROUND
NO RECORDS FOR ROUNDS 1, 6, 9, 15, 20
BASED ON MEASUREMENTS NORMAL TO A LINE FROM THE GUIDANCE RADAR ON BEARING 355 DEGREES, ELEVATION 19 DEGREES

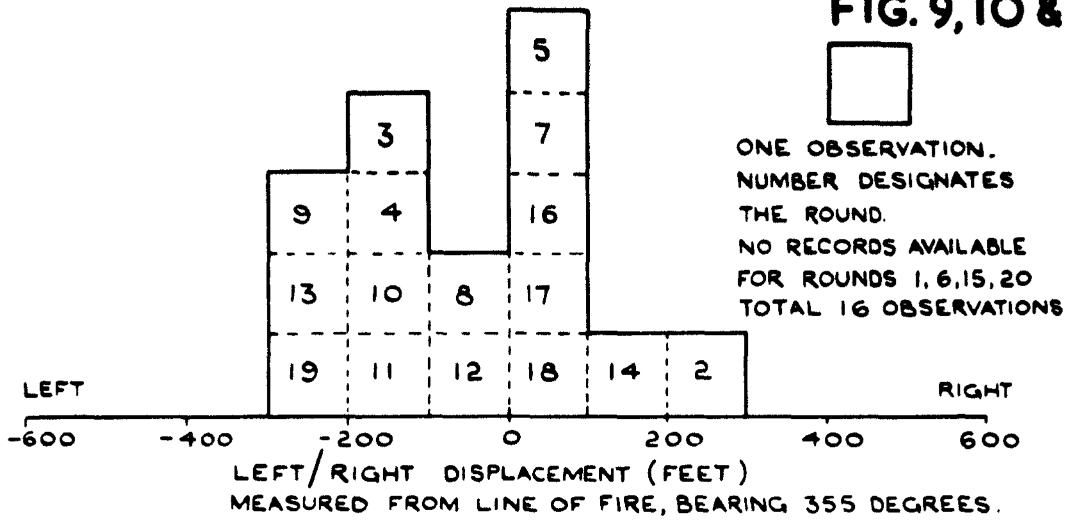

FIG. 9 L/R DISPLACEMENT OF MISSILE 4 SECS AFTER FIRING.

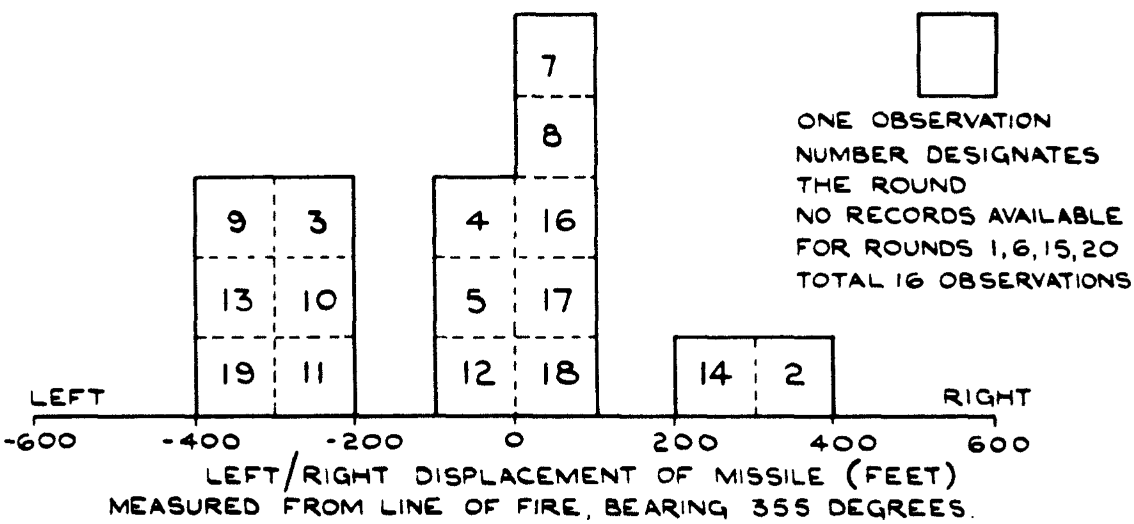

FIG. 10 L/R DISPLACEMENT OF MISSILE 5 SECS AFTER FIRING.

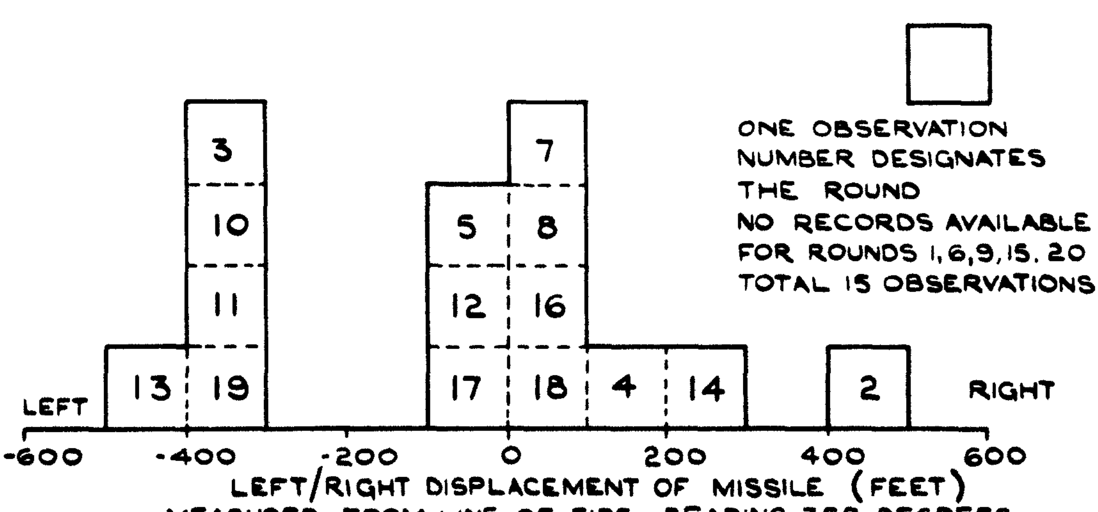

FIG. 11 L/R DISPLACEMENT OF MISSILE 6 SECS AFTER FIRING.

FIG. 12, 13 & 14

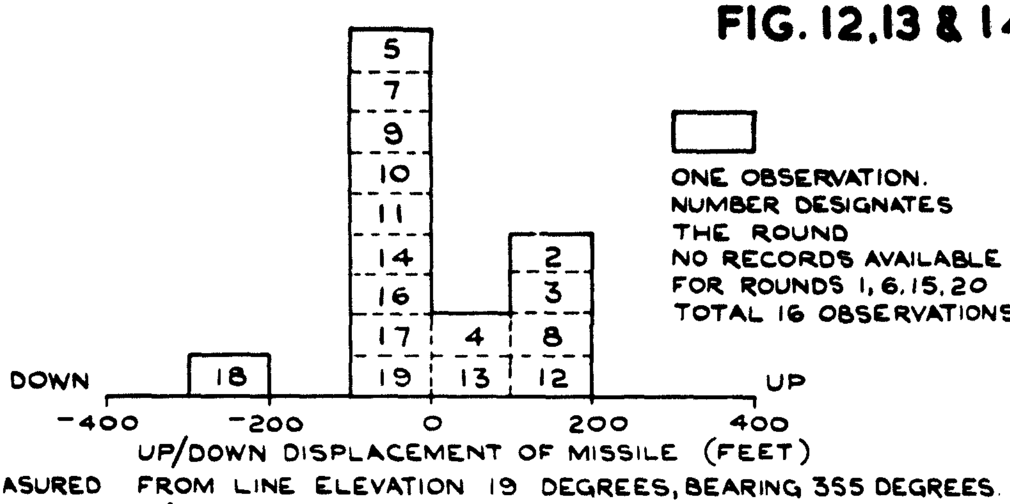

FIG. 12 U/D DISPLACEMENT OF MISSILE 4 SECS AFTER FIRING.

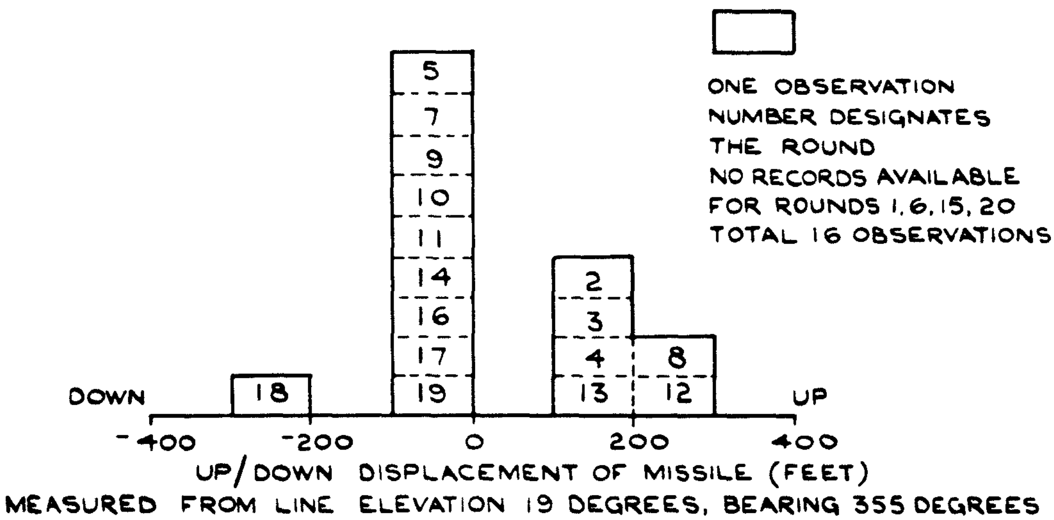

FIG. 13 U/D DISPLACEMENT OF MISSILE 5 SECS AFTER FIRING.

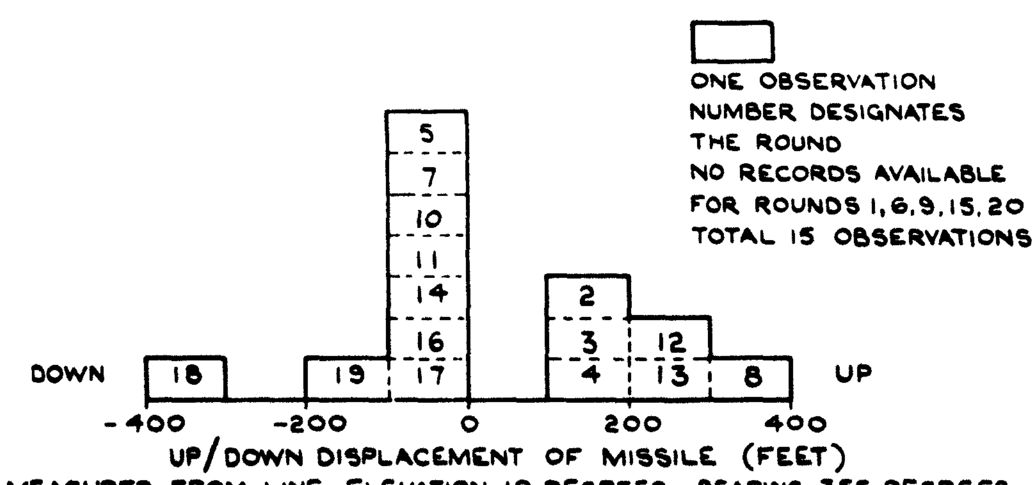

FIG. 14 U/D DISPLACEMENT OF MISSILE 6 SECS AFTER FIRING.

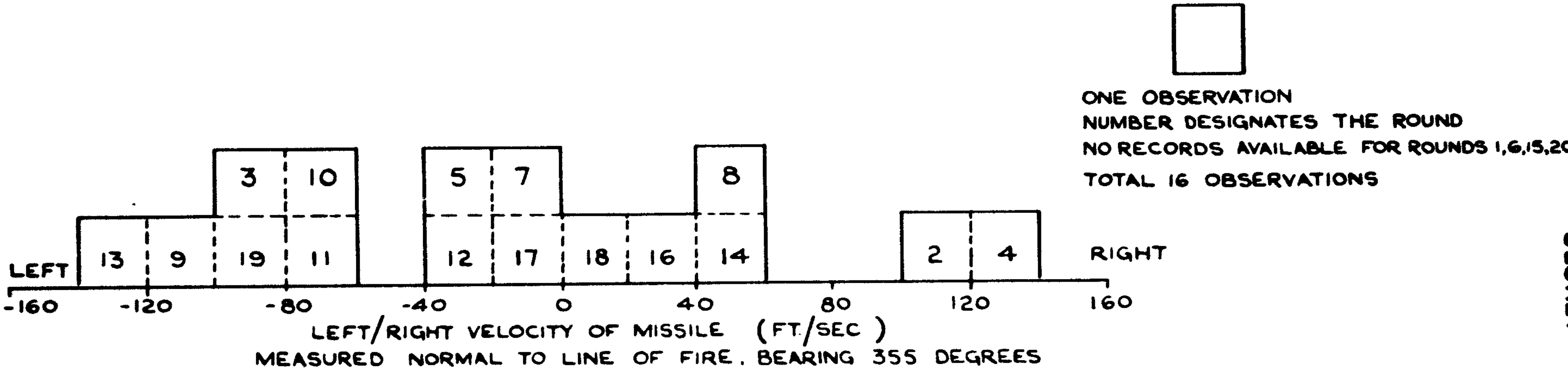

FIG.15 L/R VELOCITY OF MISSILE BETWEEN 4 AND 5 SECS AFTER FIRING.

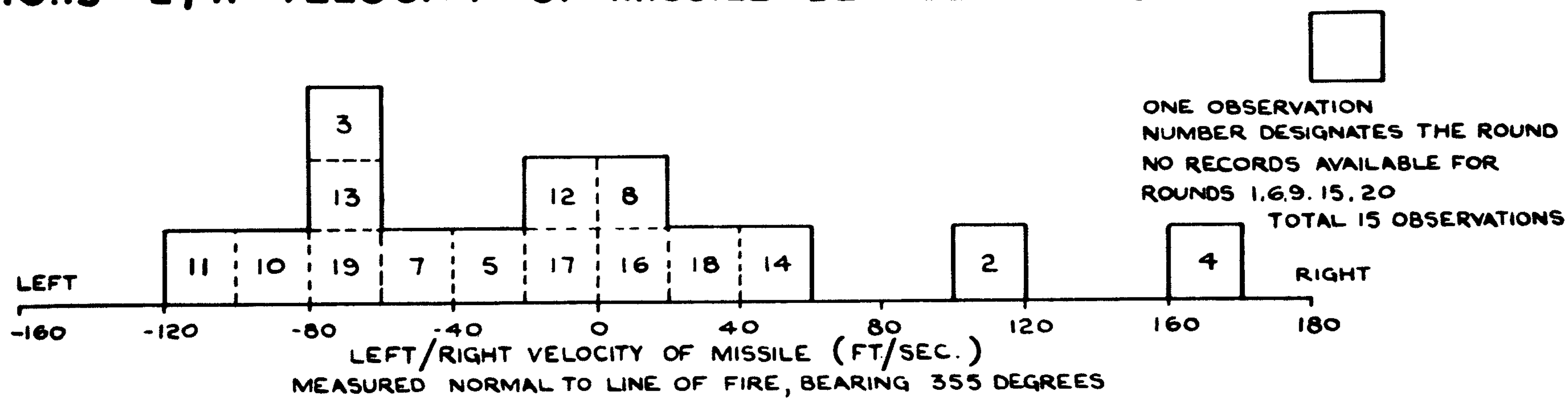

FIG.16 L/R VELOCITY OF MISSILE BETWEEN 5 AND 6 SECS AFTER FIRING.

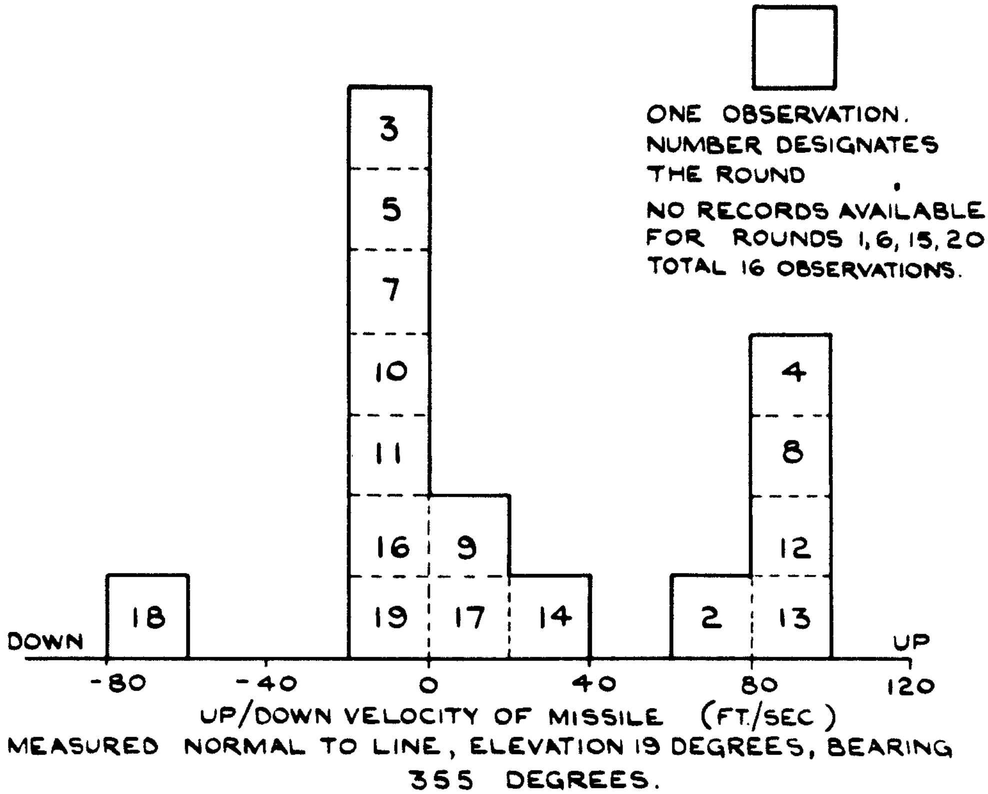

FIG. 17 U/D VELOCITY OF MISSILE BETWEEN 4 AND 5 SECONDS AFTER FIRING.

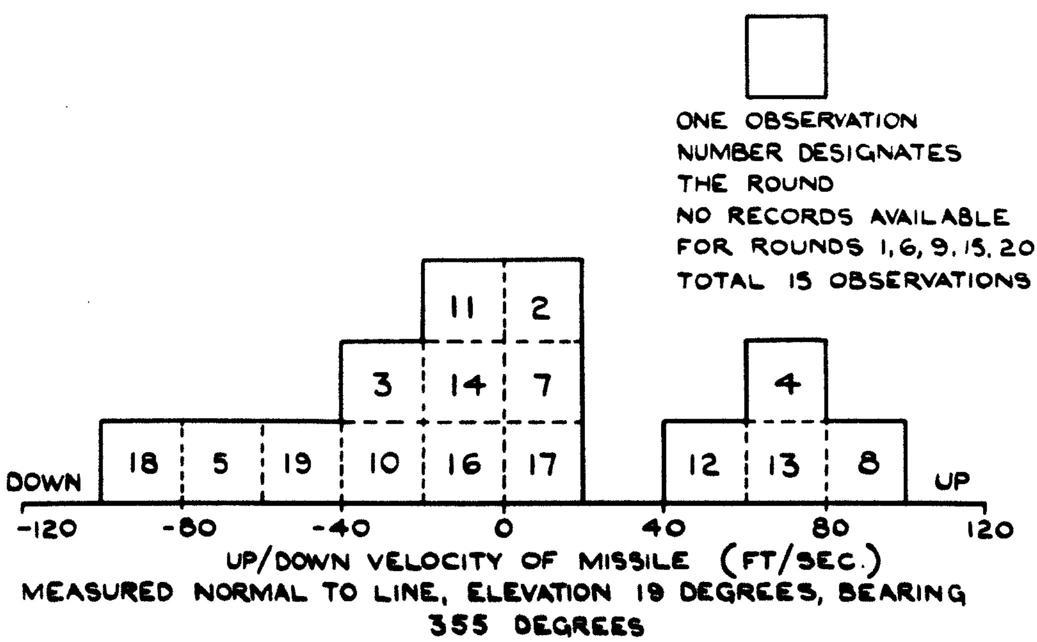

FIG. 18 U/D VELOCITY OF MISSILE BETWEEN 5 AND 6 SECONDS AFTER FIRING.

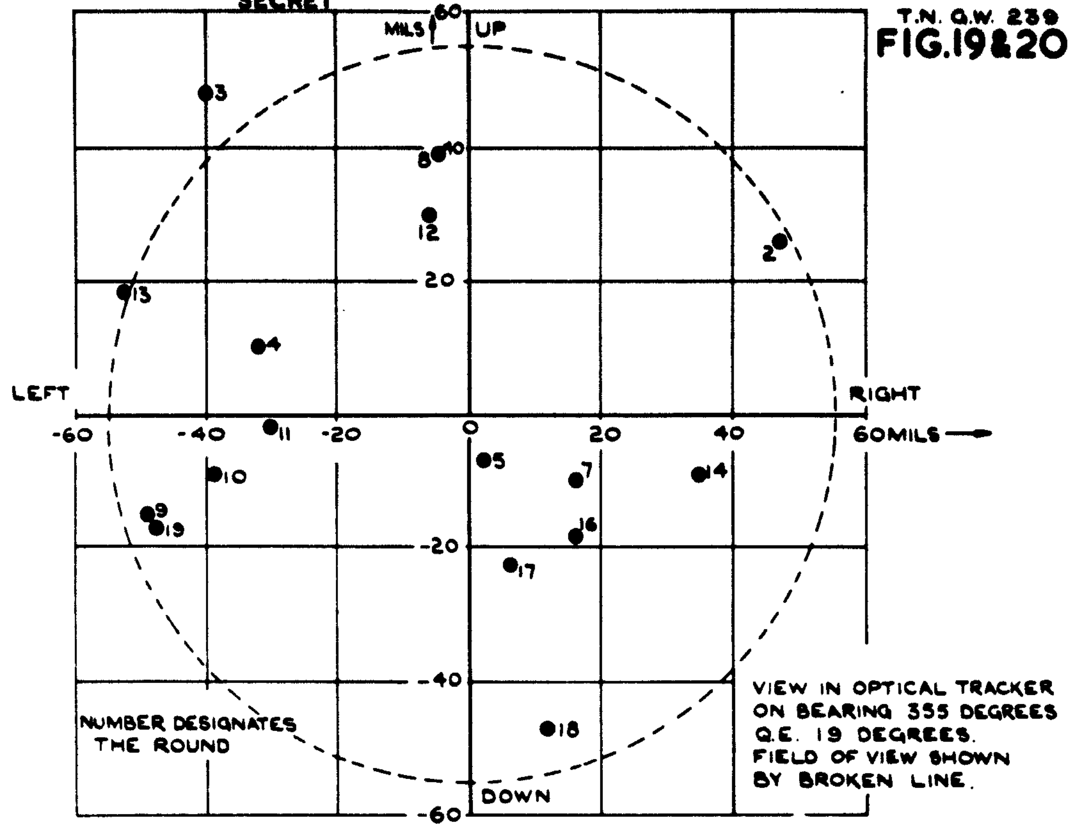

FIG.19 ANGULAR POSITION OF ROUND 4 SECONDS AFTER FIRING.

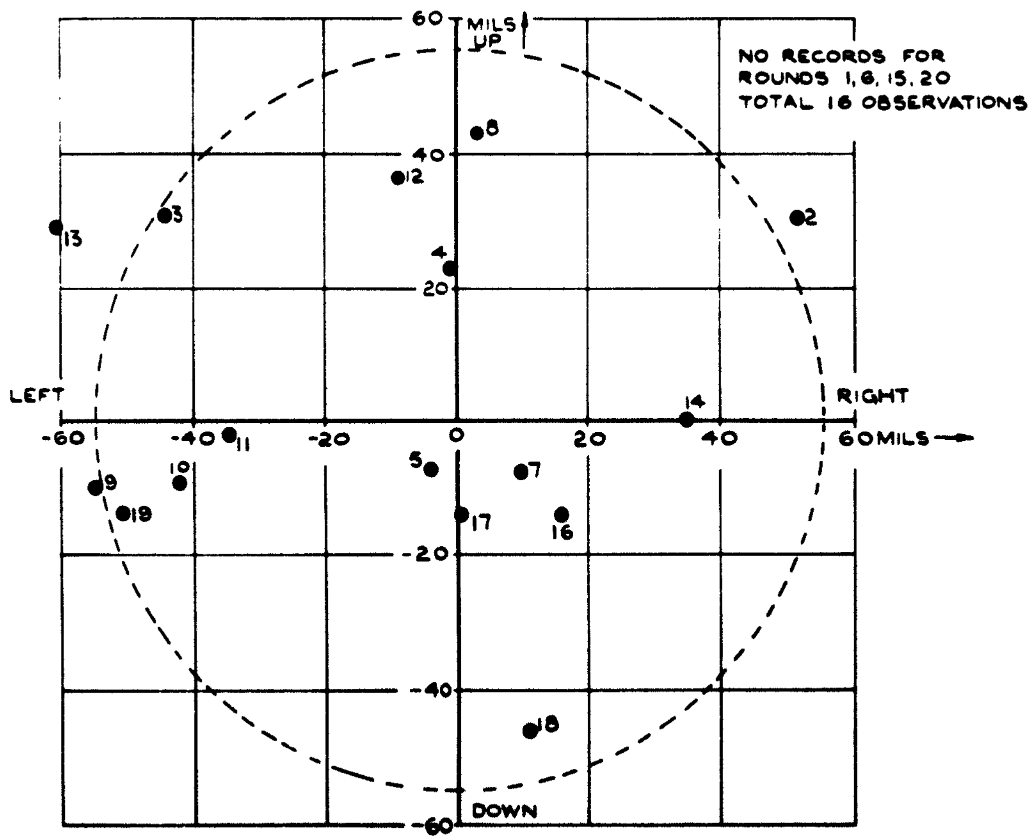

FIG.20 ANGULAR POSITION OF ROUND 5 SECONDS AFTER FIRING.

FIG. 21

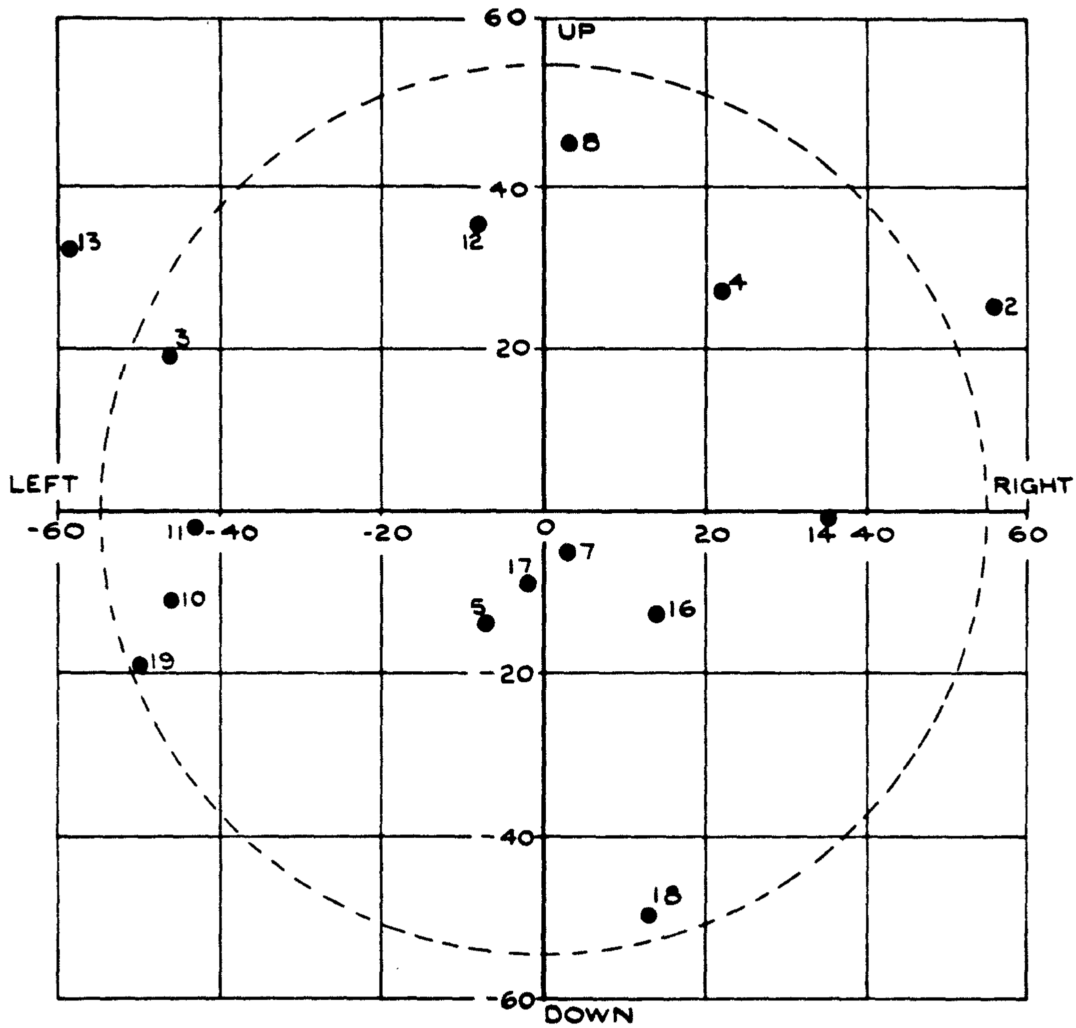

FIG. 21 ANGULAR POSITION OF ROUND 6 SECONDS AFTER FIRING.

NUMBER DESIGNATES ROUND
VIEW IN OPTICAL TRACKER ON
BEARING 355 DEGREES
Q.E. 19 DEGREES
FIELD OF VIEW SHOWN BY BROKEN LINE
NO RECORDS FOR ROUNDS 1, 6, 9, 15, 20
TOTAL 15 OBSERVATIONS

FIG. 22, 23 & 24

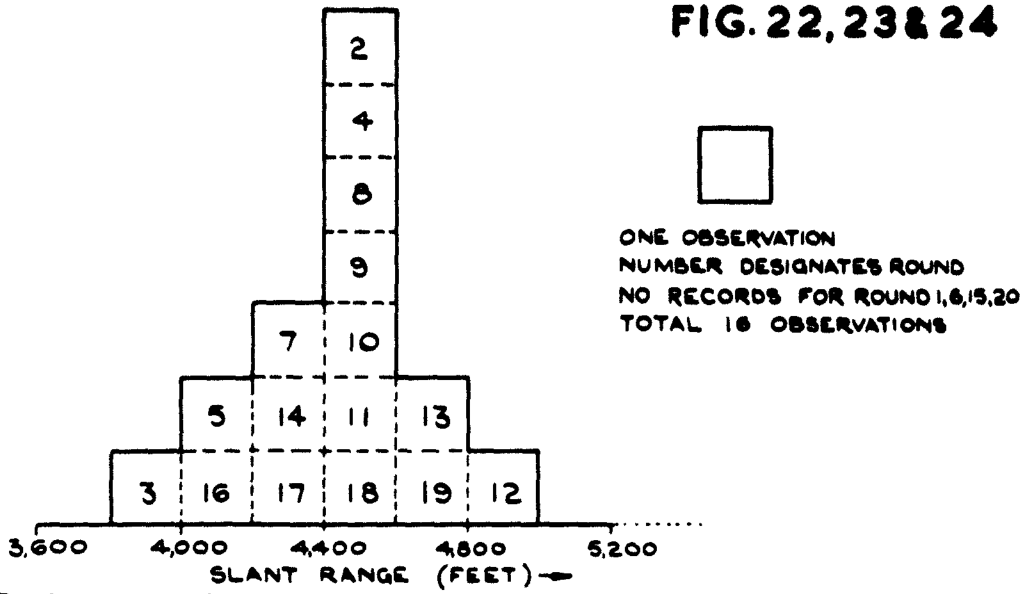

FIG. 22 SLANT RANGE OF ROUND 4 SECONDS AFTER FIRING.

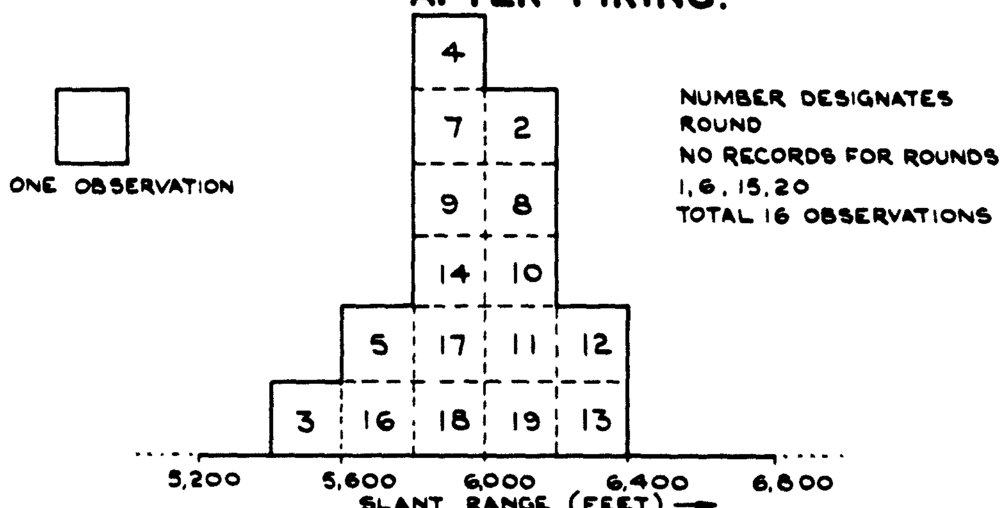

FIG.23 SLANT RANGE OF ROUND 5 SECONDS AFTER FIRING.

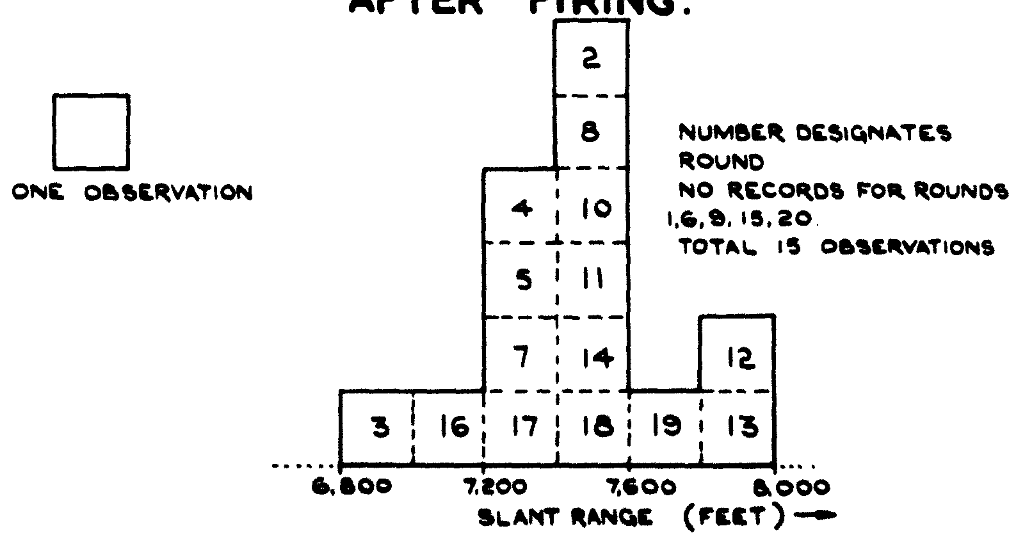

FIG.24 SLANT RANGE OF ROUND 6 SECONDS AFTER FIRING.

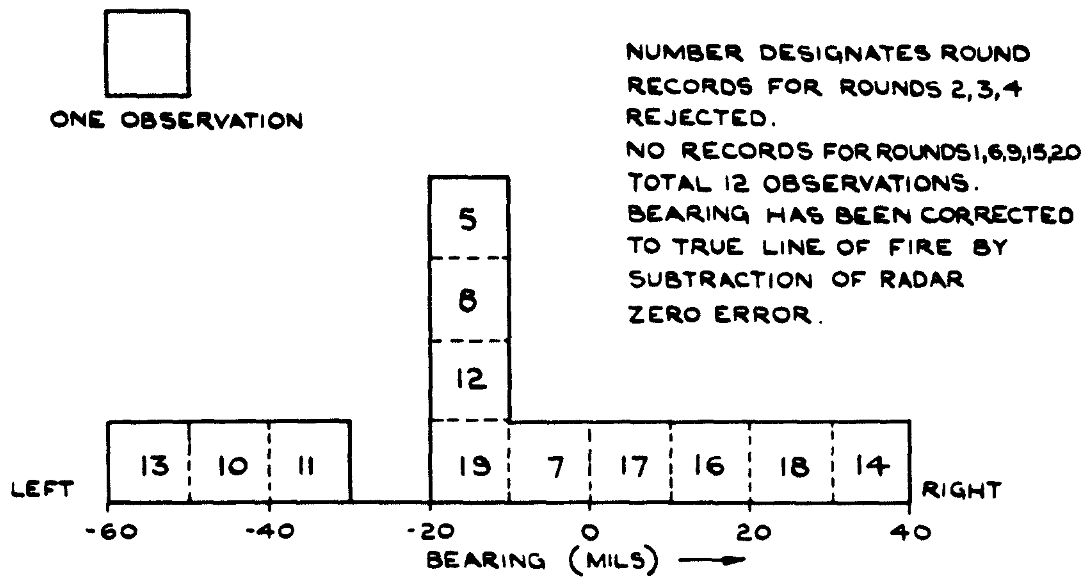

FIG.25 BEARING OF RADAR BEAM WHEN MISSILE IS GATHERED.

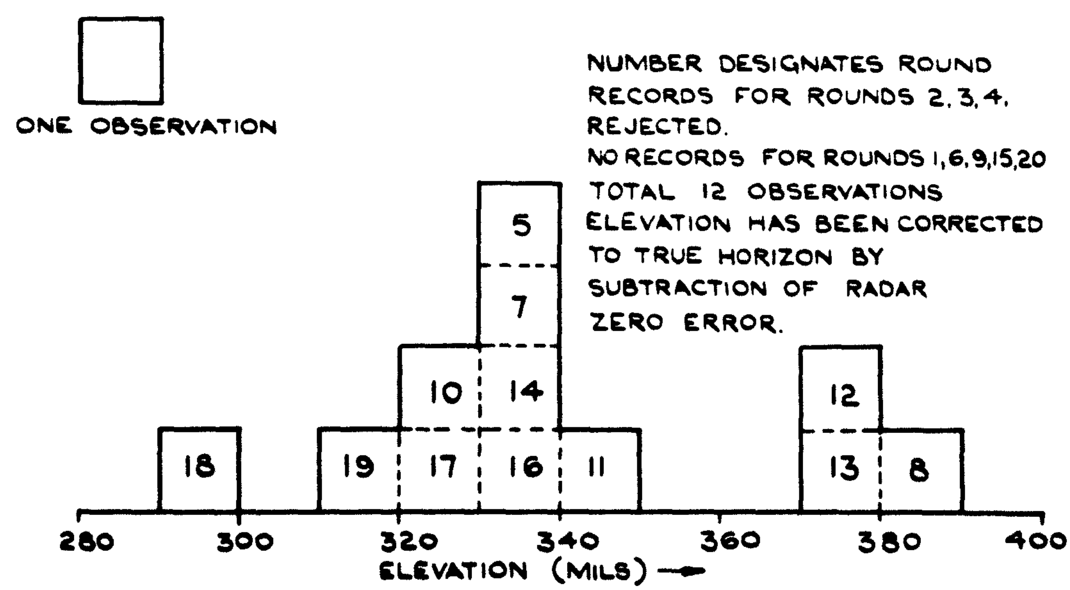

FIG. 26 ELEVATION OF RADAR BEAM WHEN MISSILE IS GATHERED.

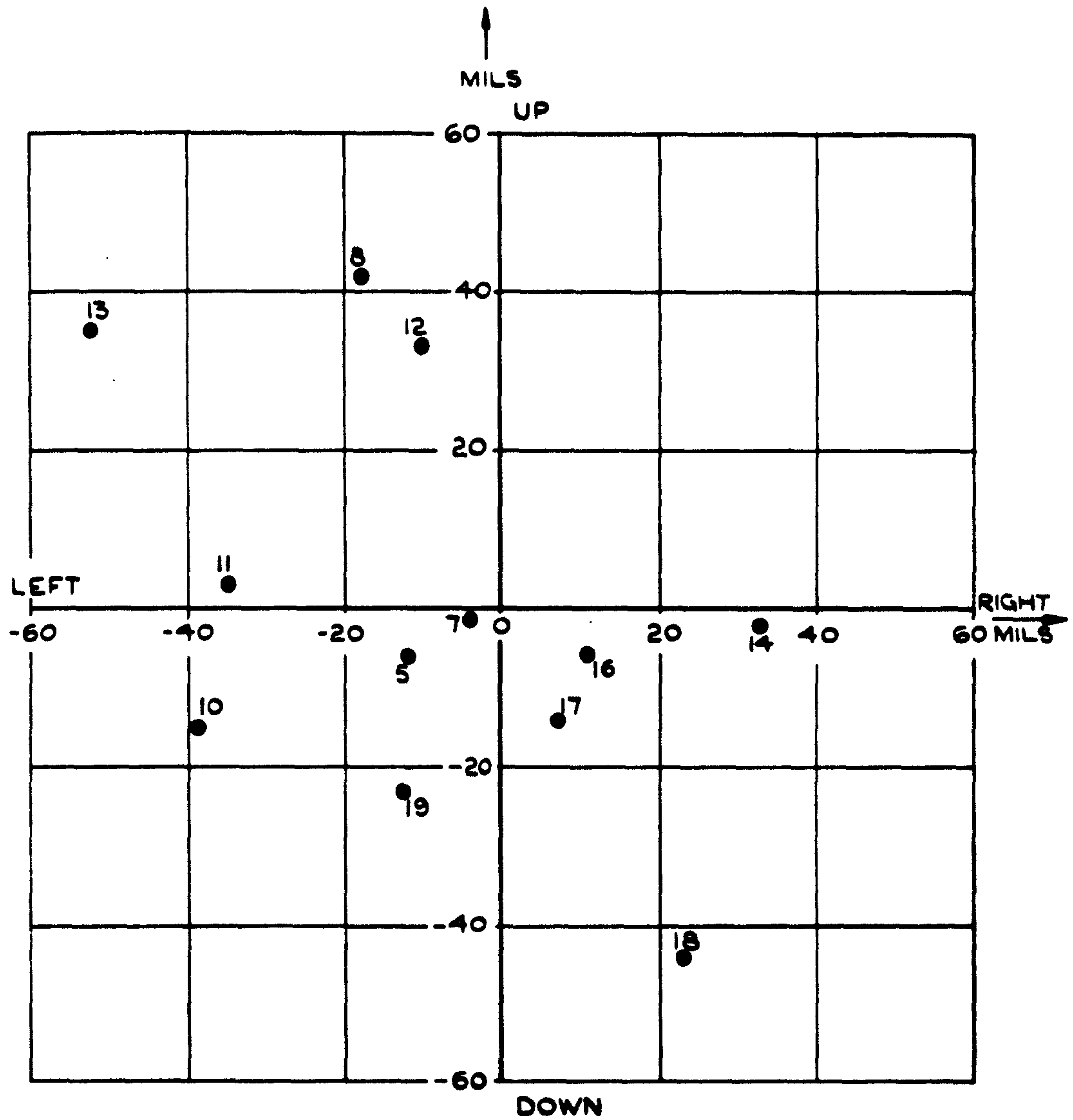

FIG. 27 STEADY BEAM POSITION FOR GATHERING MISSILE.

VIEWED FROM RADAR REFERRED TO A LINE ON BEARING 355 DEGREES, ELEVATION 19 DEGREES
NUMBER DESIGNATES THE ROUND
NO RECORDS AVAILABLE FOR ROUNDS 1,2,3,4,6,9,15,20
TOTAL 12 OBSERVATIONS.

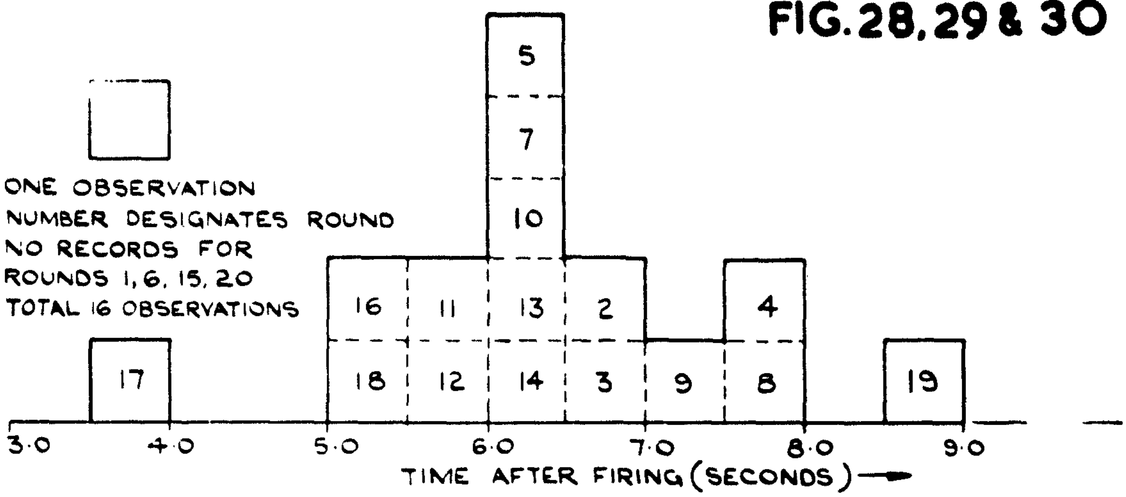

FIG. 28 TIME WHEN ELEVATION OF GUIDANCE BEAM STEADIES.

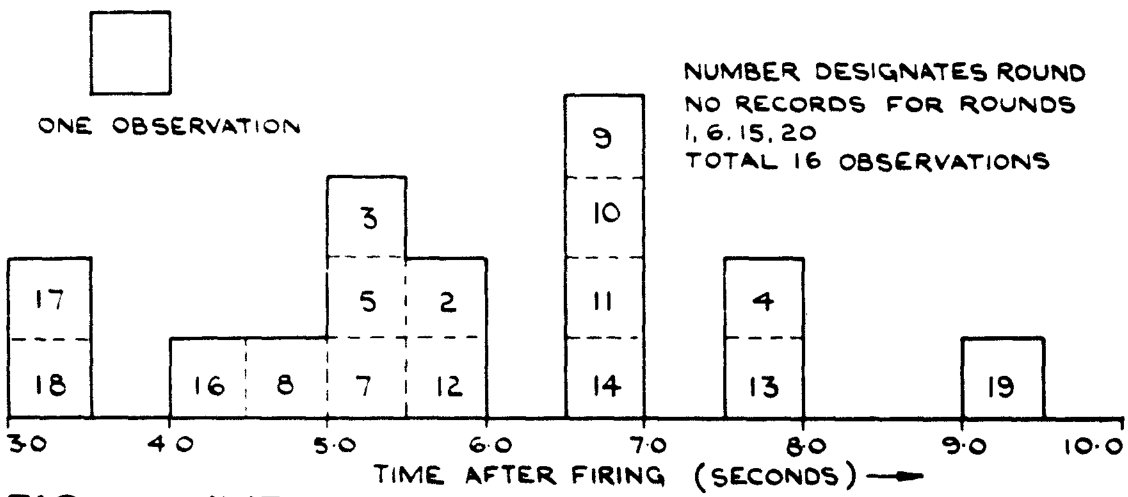

FIG. 29 TIME WHEN BEARING OF GUIDANCE BEAM STEADIES.

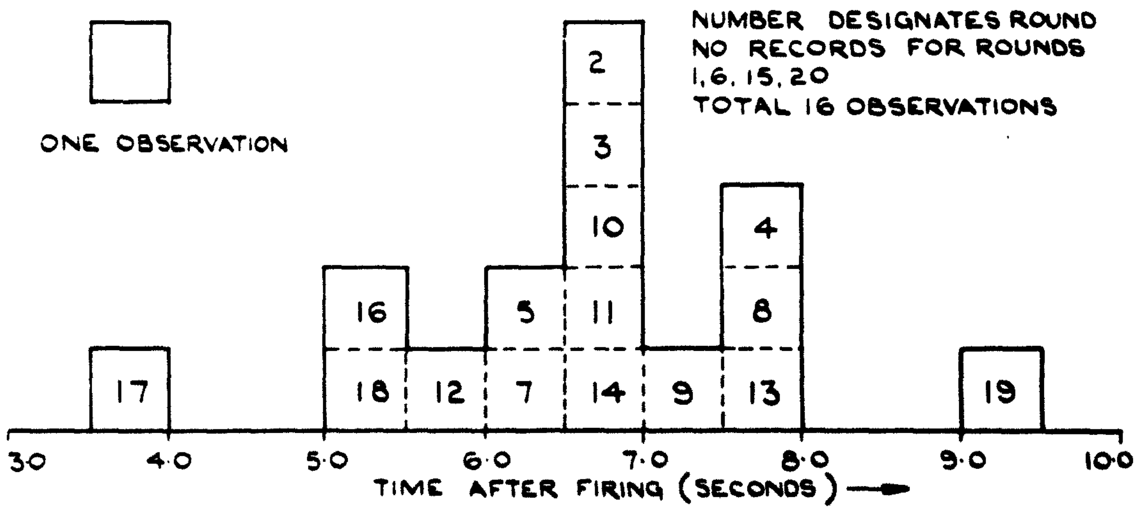

FIG. 30 TIME WHEN GUIDANCE BEAM STEADIES.

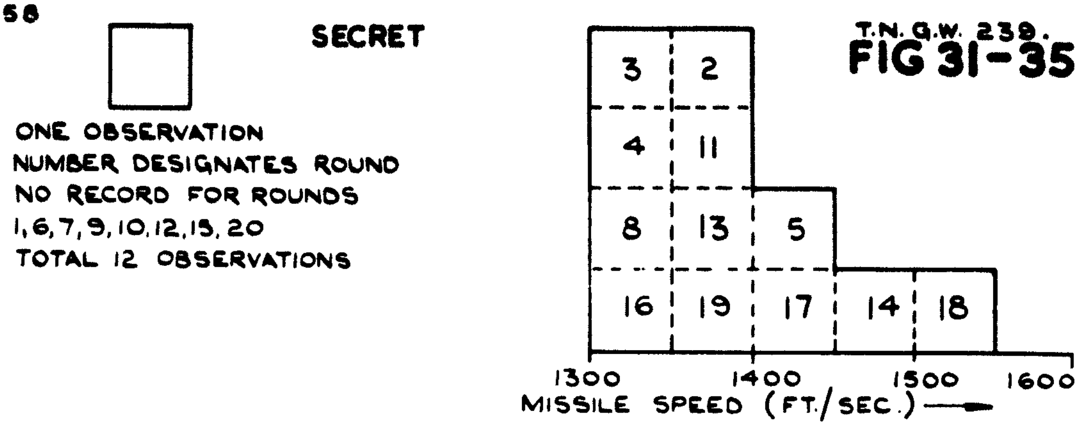

FIG.31 MISSILE SPEED 10 SECS AFTER FIRING.

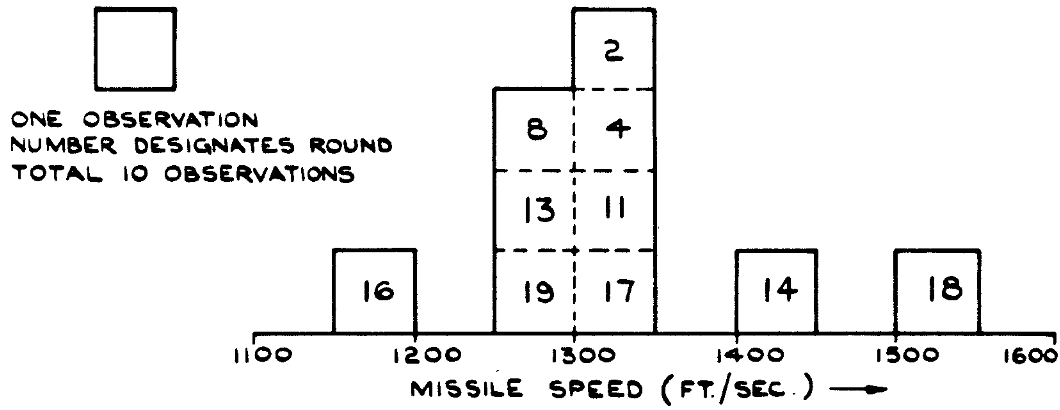

FIG.32 MISSILE SPEED 15 SECS AFTER FIRING.

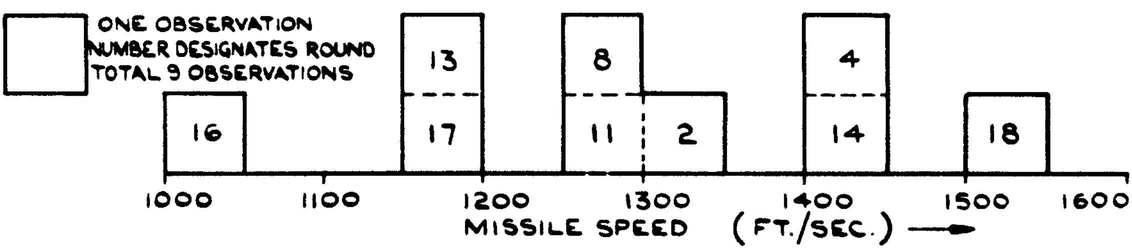

FIG.33 MISSILE SPEED 20 SECS AFTER FIRING.

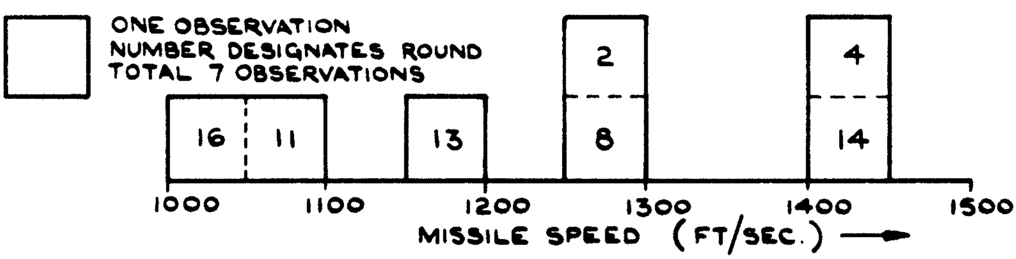

FIG. 34 MISSILE SPEED 25 SECS AFTER FIRING.

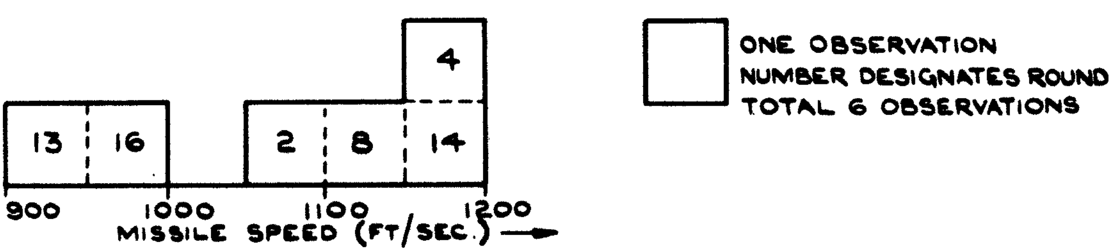

FIG.35 MISSILE SPEED 30 SECS AFTER FIRING.

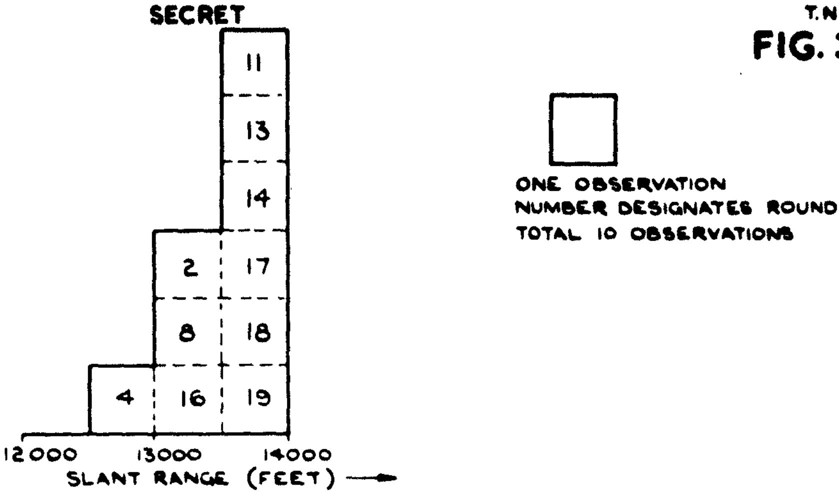

FIG. 36 SLANT RANGE OF MISSILE 10 SECONDS AFTER FIRING.

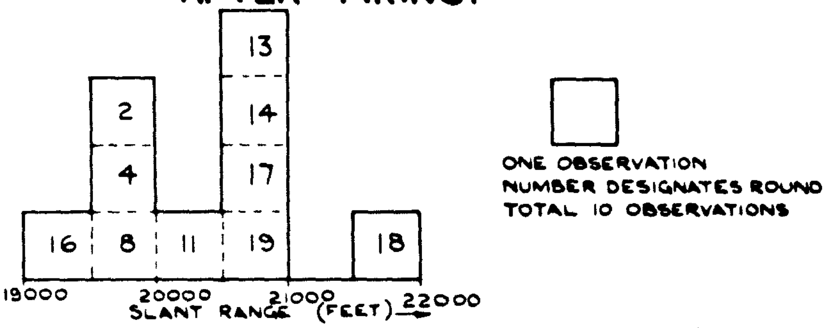

FIG. 37 SLANT RANGE OF MISSILE 15 SECONDS AFTER FIRING.

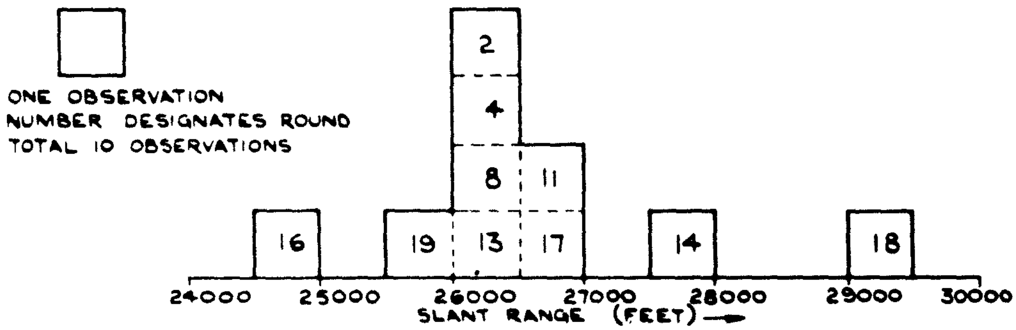

FIG. 38 SLANT RANGE OF MISSILE 20 SECONDS AFTER FIRING.

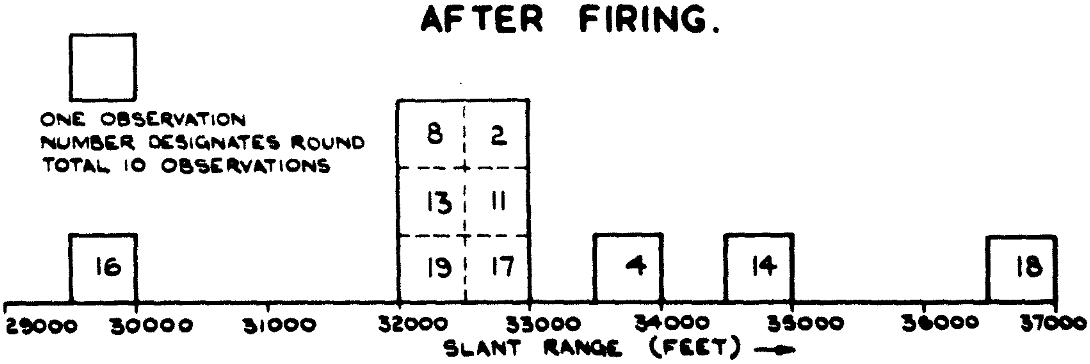

FIG. 39 SLANT RANGE OF MISSILE 25 SECONDS AFTER FIRING.

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FIG. 40

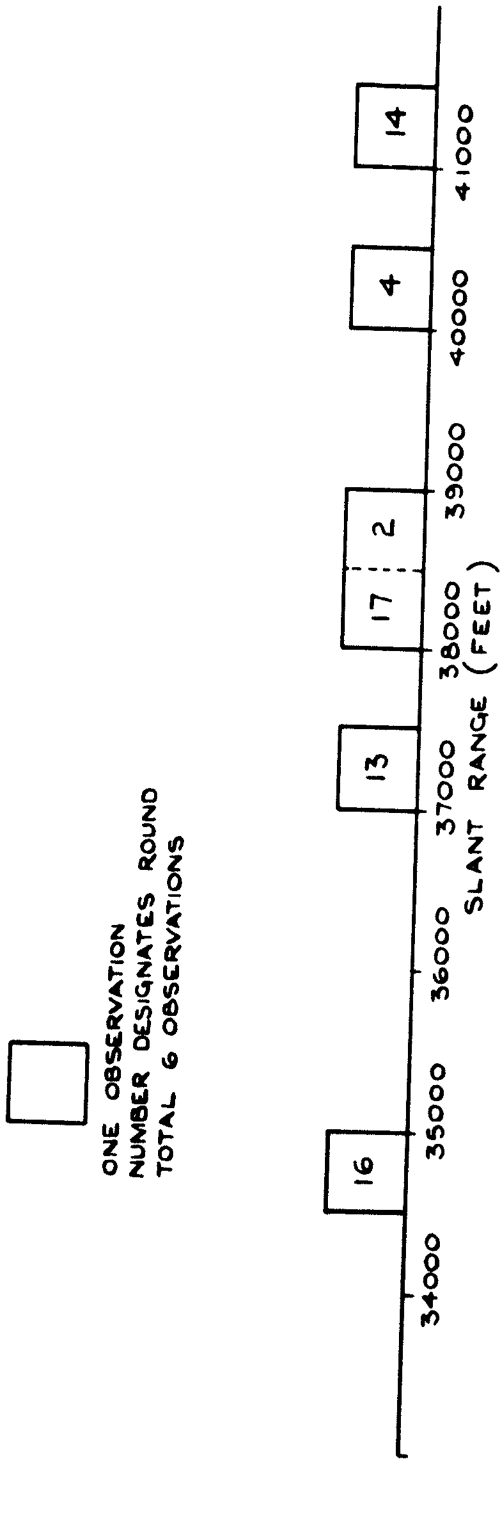

FIG. 40 SLANT RANGE OF MISSILE 30 SECONDS AFTER FIRING.

THIS HISTOGRAM IS PLOTTED TO SAME SCALE AS FIGS 36-39 ABOVE.

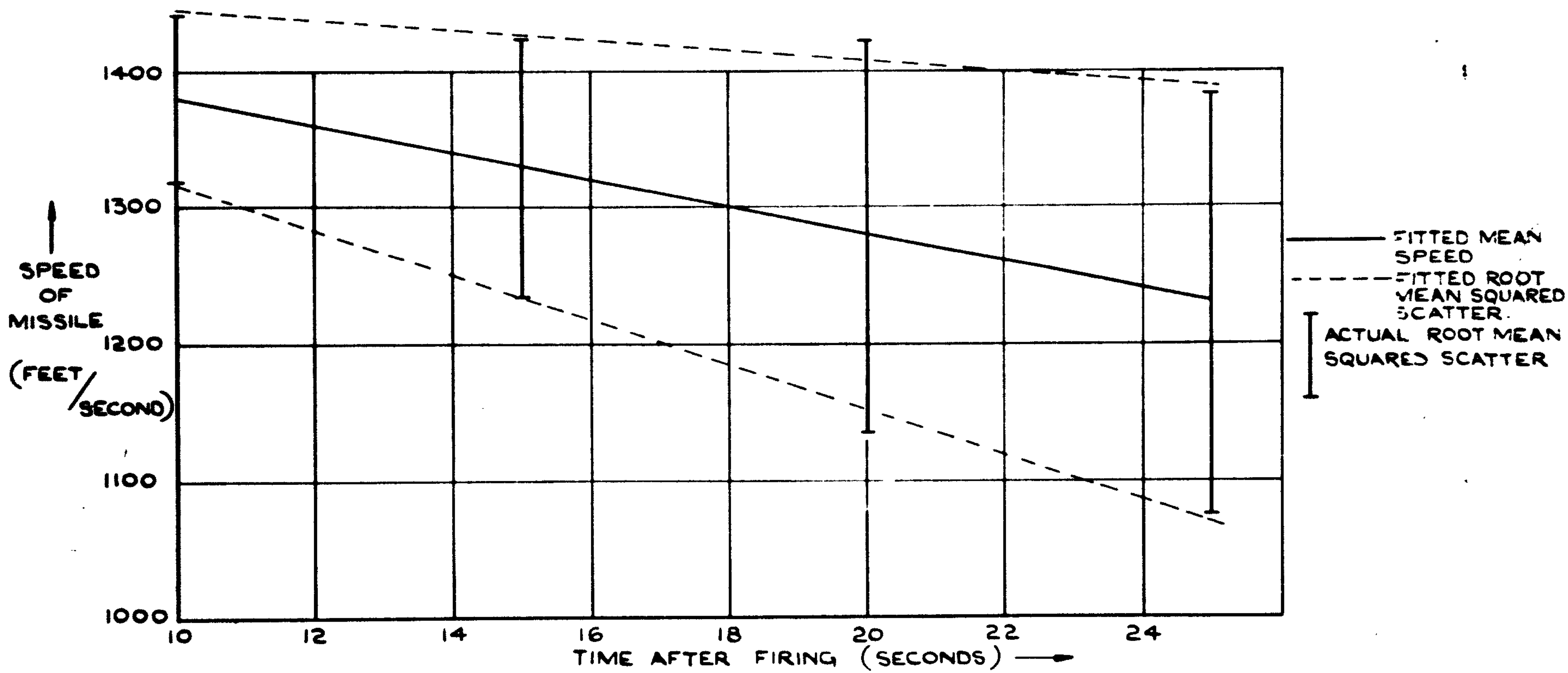

FIG. 41 AVERAGE SPEED OF MISSILE DURING PROGRAMME.

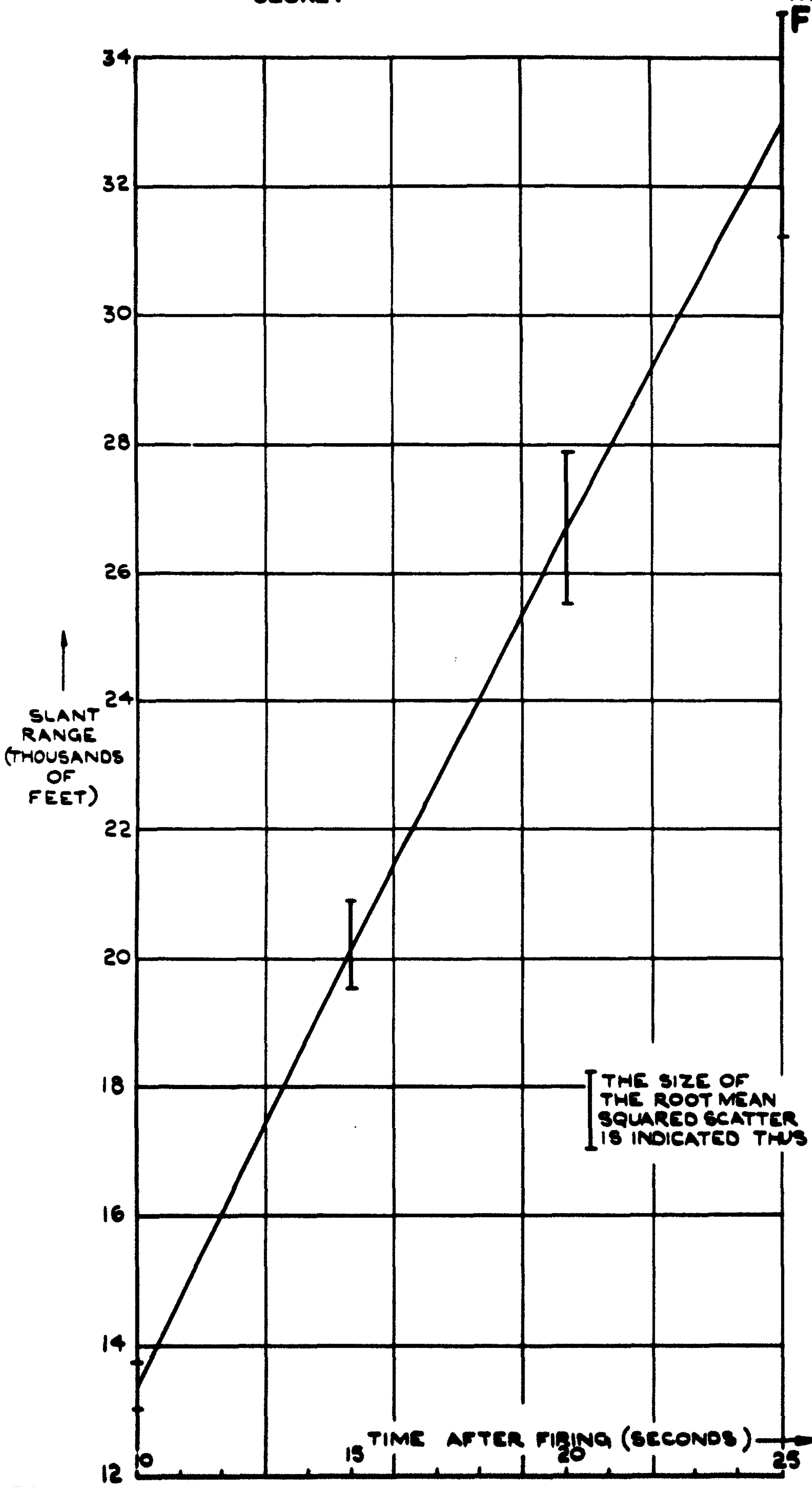

FIG.42 MEAN SLANT RANGE OF MISSILES DURING PROGRAMME.

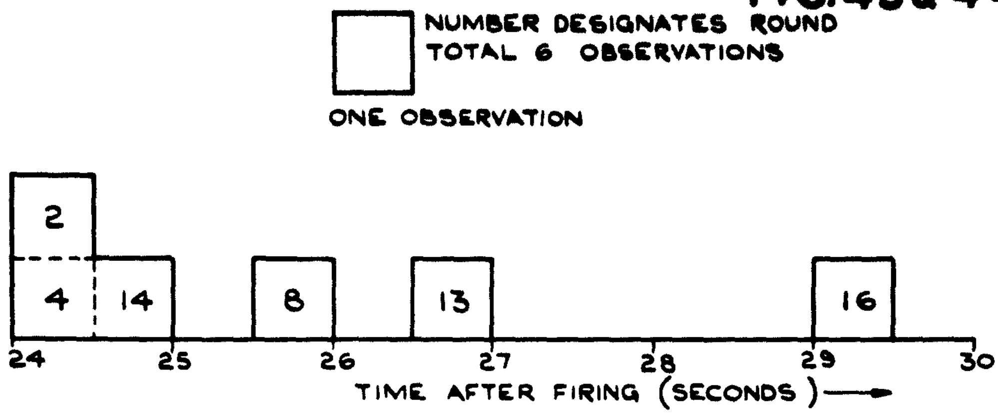

FIG. 43 TIME AFTER FIRING WHEN MOTOR THRUST CEASES.

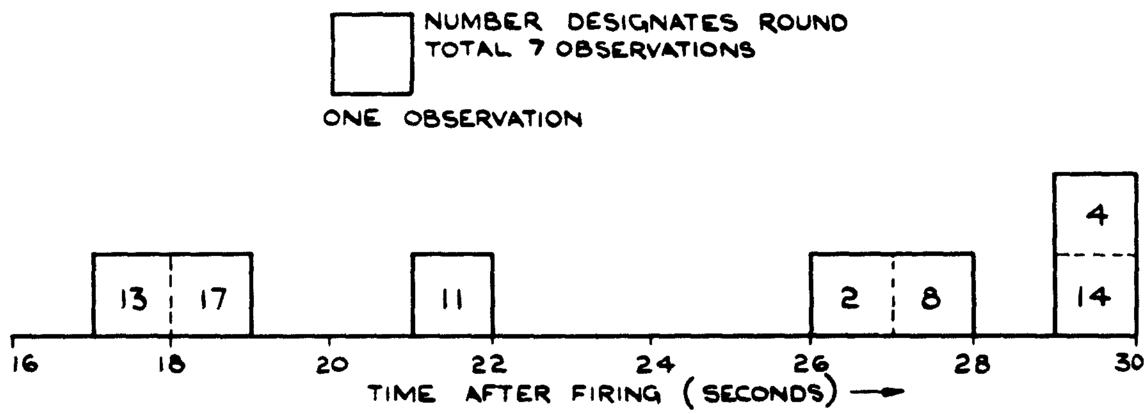

FIG. 44(a) TIME AFTER FIRING WHEN SPEED DROPS TO 1200 FEET PER SECOND.

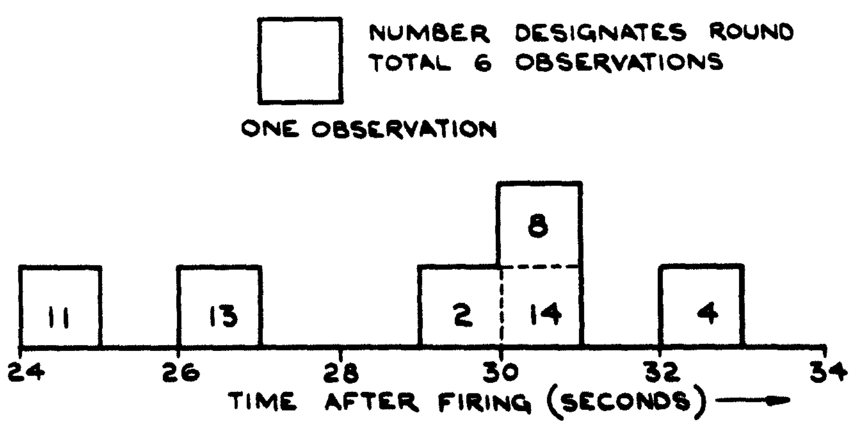

FIG. 44(b) TIME AFTER FIRING WHEN SPEED DROPS TO 1100 FEET PER SECOND.

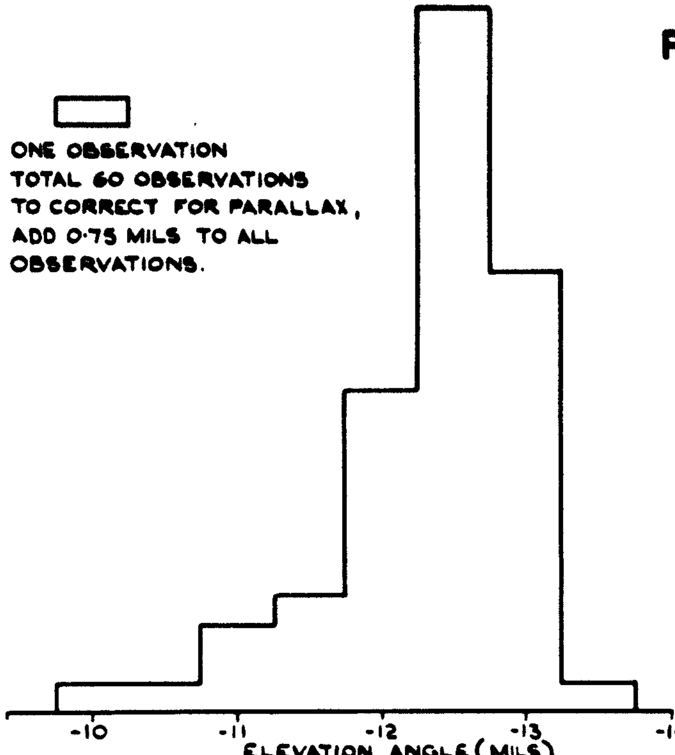

FIG. 45 ELEVATION OF BEAM RIDING DIRECTION RELATIVE TO THE AXIS OF FIXED REFERENCE TELESCOPE.

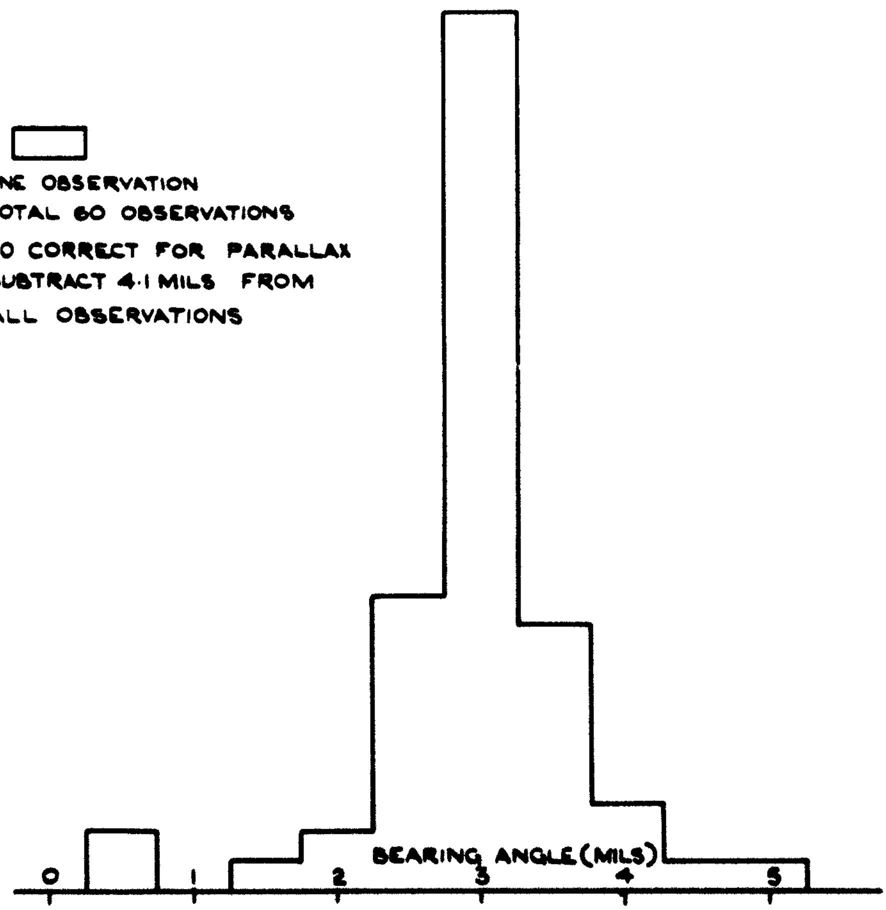

FIG. 46 BEARING OF BEAM RIDING DIRECTION RELATIVE TO THE AXIS OF THE FIXED REFERENCE TELESCOPE.

FIG.47 & 48

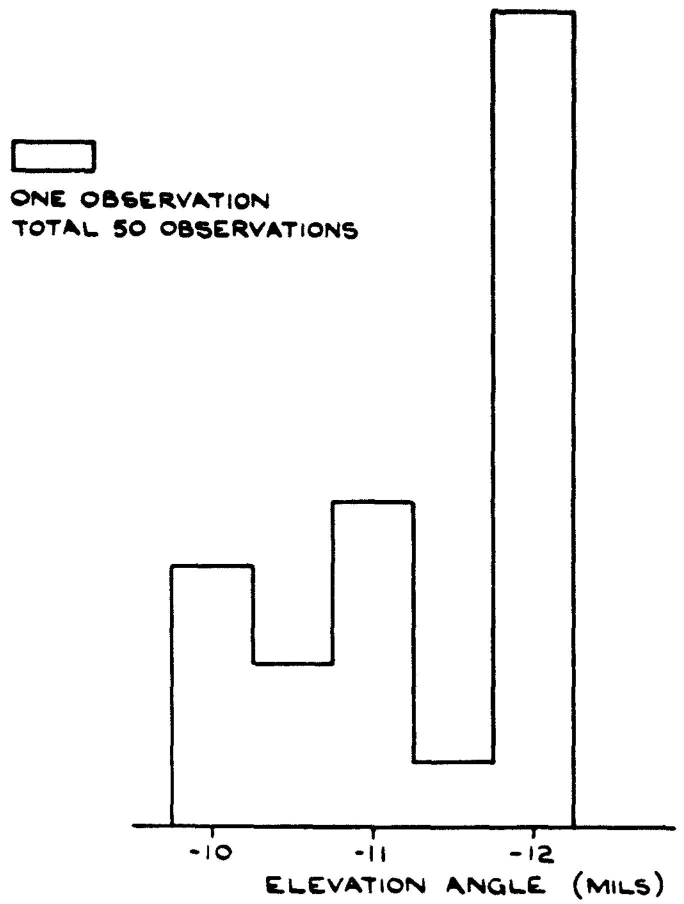

FIG.47 ELEVATION OF MOVABLE REFERENCE TELESCOPE RELATIVE TO FIXED REFERENCE TELESCOPE.

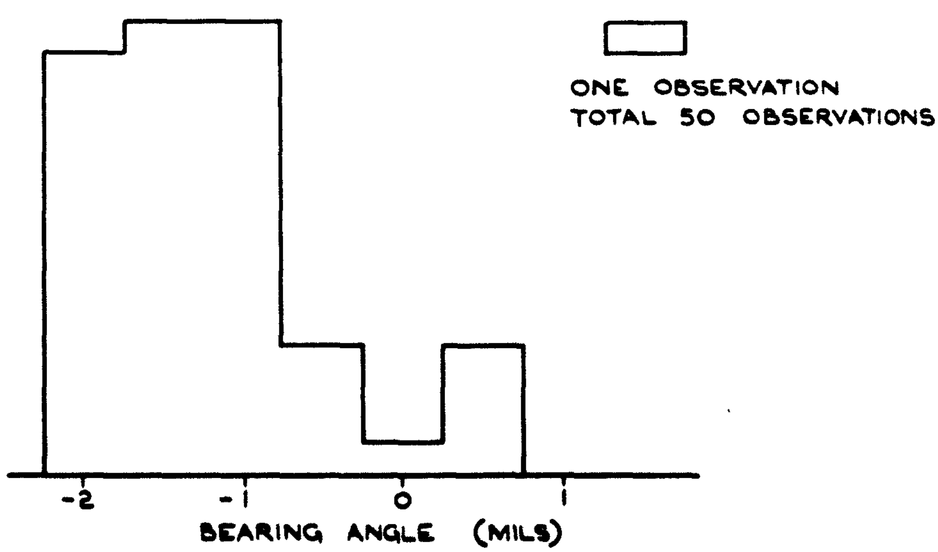

FIG 48 BEARING OF MOVABLE REFERENCE TELESCOPE RELATIVE TO FIXED REFERENCE TELESCOPE.

FIG. 49

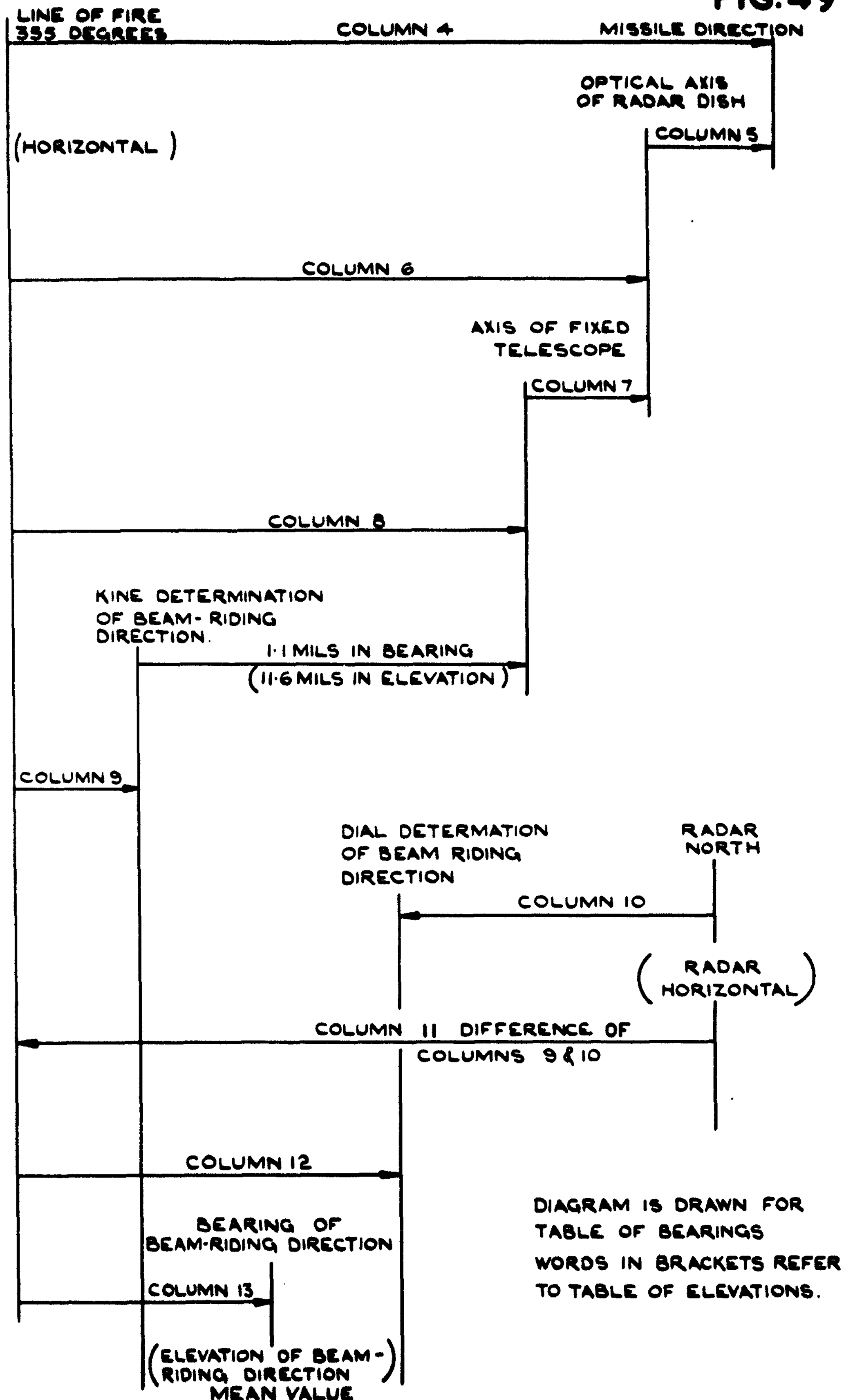

FIG. 49 DIAGRAMMATIC REPRESENTATION OF TABLES IN APPENDIX V

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Royal Aircraft Estab. Tech Note No. GW 239
1953.3
Longden, G. B.

623.451-519(42)RTV1:
†621.396.965.81:
531.567

SOME DATA ON RTV1 FIRINGS RELEVANT TO FUTURE BEAM-RIDING TRIALS

By mid-June 1952, twenty missiles of the type RTV1c had been fired at Guided Weapons Trials Wing, Aberporth, in the course of the beam-riding Trial C40. This appears to mark an appropriate time to assess some of the features of the trial which are subject to random variations and call for statistical analysis. These include the times of various events in the course of a firing, as well as the slant range, velocity and dispersion of the missile. Means and root mean squared scatters about the means are quoted for some forty variables, and the distributions of the observations shown diagrammatically by means of histograms.

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